STATION BUSINESS DEPARTMENT (continued)

STATION ENGINEERING DEPARTMENTS

General

Carrier-Current Radio

Broadcast Audio

Intercollegiate Broadcasting System

ENGINEERING CODE

Each IBS member station shall operate in accordance with the following technical standards. Waivers may be granted by the IBS Engineering Manager, for good cause.

A. All stations shall have at least the following studio facilities:

1. Two separately attenuated microphone channels and microphones.

2. Two phonograph turntables with an electrical cuing circuit.

3. One separately attenuated input for remote lines, which may be derived by instantaneous switching of a phonograph channel if two separately attenuated phonograph channels are provided.

4. One tape player capable of reproducing 7-inch reels, recorded half or full track, at 7 1/2 inches per second.

5. Loudspeaker and headphone monitoring facilities in all regularly used studios and control rooms.

6. A Volume-unit meter with suitable dynamic characteristics (per American Standards Association C16.5-1954) on the program output signal.

B. All stations shall keep an operating log and record in it the following data on each transmitter or cable modulator operated:

1. The exact time carrier and modulation are applied and removed each day.

2. The nature, cause, and duration of each interruption in service.

3. Other information as applicable

The log shall be retained for two years and made available for examination by the IBS Engineering Manager or an authorized FCC official.

C. All stations operating nonlicensed restricted-radiation (carrier-current) systems shall meet the following standards:

1. The nominal carrier frequency shall be between 530 and 890 kHz, and shall be an exact multiple of 10 kHz. The transmitter(s) shall operate within $\pm$ 40 Hz of the nominal frequency.

-More-

2. The system shall not operate on the same channel as a licensed station whose 500 uV/m contour encloses any part of the service area of the carrier current station, or on the first or second channel adjacent to any licensed station whose 2 mV/m contour encloses any part of the service area. Spurious signals generated in the transmitter or radiating line shall not contravene these requirements

3. The system shall operate in accordance with Parts 15.1-15.7 (and, where relevant, 15.204) of the FCC Rules, or, outside the United States, equivalent regulations.

4. The transmitter(s) shall be capable of at least 95% modulation.

5. Total harmonic distortion between microphone or phonograph input and transmitter output shall not exceed 7.5% at 95% modulation, measured with an applied frequency of 400 Hz.

6. Noise and hum introduced beyond the microphone input shall be at least 40 dB below the signal at 95% modulation.

7. Overall frequency response of the system between microphone input and transmitter output shall be within $\pm$ 2 dB of the 1000 Hz value between 100 and 5000 Hz, provided that this requirement does not apply to isolated transmitters serving a total of no more than 10% of the potential carrier current.

8. Systems for frequency-locking remote transmitters by means of tones on telephone cables shall operate so as not to interfere with other services using the same cable.

9. Although not required, an audio limiter and compression amplifier are strongly reccomended.

10. The carrier frequency shall be measured, by means independent of the transmitter frequency control, under the following conditions:

    a. when the transmitter is installed;

    b. any time that the frequency-determining element(s) are changed or adjusted;

    c. any time the carrier frequency is believed to be beyond the tolerance specified above.

11. Transmitter adjustments and input-power measurements shall be logged whenever made, and retained for a period of two years.

-More-

D. All stations originating signals on a cable television (CATV) or master antenna (MATV) system shall meet the following standards:

1. Systems operating without paid advertising shall provide frequency response, distortion level, and hum and noise capable of providing satisfactory broadcast service.

2. Systems operating with paid advertising shall:

   a. if operating as the sound portion of any television channel except Channel 6, provide frequency response, distortion level, and hum and noise levels capable of providing satisfactory broadcast service;

   b. if operating as the sound portion of television Channel 6, or operating on any frequency between 87 and 109 MHz, provide audio response equivalent to commercial FM standards as stated in Part 73.317 of the FCC Rules. These are: frequency response $\pm$ 2 dB, 500-15000 Hz (Part 73.317(a)(2)); total distortion (Part 73.317(a)(3)) less than 3.5% RMS with modulating frequencies between 50 and 100 Hz, less than 2.5% between 100 and 7500 Hz, less than 3.0% between 7500 and 15000 Hz; hum and noise level (Part 73.317 (a)(4)) at least 60 dB below 100% modulation at 400 Hz.

3. All systems, regardless of commercial or noncommercial status or of operating frequency, shall provide off-the-cable monitoring at the studio location and shall adjust modulation levels so as not to interfere with licensed stations carried on the same cable. Although not required, an audio limiter and compression amplifier are strongly recommended.

E. All FCC-licensed stations shall operate in compliance with the relevant FCC Rules.

CABLE FM: 50 STATIONS AND STILL GROWING

The vigorous growth of cable FM continues with no sign of slowing, and the number of operating stations has passed fifty.

Counted as cable FM are only those operations which provide true local-origination radio on a cable system. A licensed FM station which happens to appear on cable is not CAFM for our purposes, nor is the rebroadcasting of non-FM stations. Likewise, straight background music origination by cable operators doesn't count.

The prospect of interference before the FCC by broadcaster groups seems relatively remote at the time of writing. Thanks to stations which returned the IBS cable questionairre, we think we can conclusively demonstrate the value to the public of local-origination radio. The National Cable Television Association reportedly feels the same way. After all, if the FCC has seen fit to require local origination of television on cable, it would hardly be consistent to hamper locally-originated radio.

We also feel that the promotional activities surrounding a CAFM operation are beneficial to on-the-air FMs as well. They publicize the idea of "FM" radio, and persuade listeners to buy sets and to wire them to the cable. The listener then gets improved reception of off-the-air signals, an important factor in areas with unfavorable terrain. Promotions will also stimulate sales of portable and automobile FM sets which the cable station cannot reach.

Some results from the IBS survey may be of interest. More than half the operating CAFM stations, including the three non-school operations, furnished data. Other information came from material on hand, industry directories, and equipment makers.

Figure 1 charts the growth of cable stations. If present growth continues we could easily have 75 stations by the end of 1974.

Combined carrier-current and CAFM operation remains the most common technique, but five college-related stations use CAFM alone. This includes a few community-college stations having no dormitories to cover, and thus unable to exist without CAFM or licensed radio.

Student control is the usual thing. All known college CAFMs, with one possible exception, are student managed.

For various reasons, including copyright coverage, 70% of the school-related CAFMs are IBS members.

Figure 2 shows the stations' audience potential, in terms of CATV-equipped households reached, including the effects of stations which appear

-More-

on multiple cable systems. The median potential audience is about 3900. About 16% of all CAFMs serve fewer than 1000 taps, and 14% more than 40,000. About 524,000 households in the U. S. and Canada have access to at least one CAFM station. However, figures like these are optimistic because they fail to reflect what fraction of the households are able to receive FM from the cable, or what percent listen significantly to a CAFM station appearing on a TV sound channel. True figures would require careful audience surveys.

Exactly 33% of CAFMs are noncommercial. Figure 3 gives the distribution of advertising income for the others. The median revenue is $2000, hardly an amount to put undue pressure on on-the-air broadcasters. As with straight carrier-current, a station's commercial revenue depends heavily on the amount of other funding, the size of the station, and the success of the sales department.

The costs incurred in adding CAFM vary somewhat. All known stations which use a rented telephone line pay their own line charges. In a couple of cases the CATV operator provides transmission to the head-on on his own facilities. Three-quarters of the stations operating on FM channels own their own modulators, and have chosen solid-state types over cheaper tube models by almost three to one.

The value of CAFM as a true local service is evident from Figure 4, which shows the number of nonduplicating AM or FM stations licensed to the same community. In 24% of the cases there is <u>no</u> other local service; in 61% there are no more than two other local stations.

A third of the FM operations are on split-channel frequencies, 95.0 MHz for example. Jim Berkey of WQAX (Bloomington, Ind.) points out a useful fact: the CAFM station can operate without troublesome interference on the second-adjacent channel to another signal. Upon doing some checking, it turns out that stations in the San Francisco, Los Angeles, and New York City areas have had the same experience: they generally operate with other stations 400 kHz above and below. Interference is controllable, of course, by simply setting the CAFM signal similar in level to its neighbors. (The FCC educational-FM rules recognize this situation by allowing a second-adjacent station to be ten times as strong as its neighbor.) So CAFM can salvage commercial channels in metropolitan areas which are simply unlicensable due to mileage-separation requirements. This is true even without splitting channels.

Thirteen stations operate on TV channels, taking advantage of an existing weather-scanner modulator, and two operate TV sound and FM simultaneously.

Stereo operation is popular: 31% of the FM operations are stereo, compared with, say, 5% of Class D FM stations. The noise advantage of cable radio, and

possibly the commercial revenue to pay the doubled line costs, are important here.

Half a dozen stations feed multiple CATV systems, due usually (but not always) to use of a common head-end by the cable operator. One station appears this way on eight systems.

Educational campaigns of the how-to-receive-our-station variety appear to be a necessity with cable radio. Before issuing instructions, it would be good to agree with the cable operator on what methods of cable connection are acceptable. Some companies will insist on selling second taps, installed by their own technicians. In a few states, Indiana and Pennsylvania among them, the CATV industry has even secured legislation outlawing subscriber-added extensions, on the theory that unofficial wiring is likely to radiate in excess of the FCC's limits. In other cases, the cable operator is unconcerned about the matter. Perhaps a reasonable compromise is to regard the cable company's function as to provide a broad-spectrum signal source. A subscriber should then be within his rights in using an ordinary TV-FM splitter of the filter type to divert FM frequencies to his radio.

Some potential CAFM stations and their school administrations have come under pressure from licensed broadcasters who fear dilution of their listening audiences and advertising revenue. We have shown above that the revenue loss is miniscule. It would be appropriate, where unfair competition is charged, to offer to put an AM station on the cable along with the CAFM operation. An AM daytimer could feed the FM modulator during normal operating hours, with a switch to the college station's audio at sundown. A more costly but superior plan would be for the two stations to appear side-by-side on the cable. The broadcaster would pay for his modulator and line charges just like the CAFM station. Or he could use an AM tuner at the head-end to receive the signal directly. All concerned, including the cable operator, would benefit. The number of AMs appearing on cable in mid-1973 was 46, up from 35 a year previously.

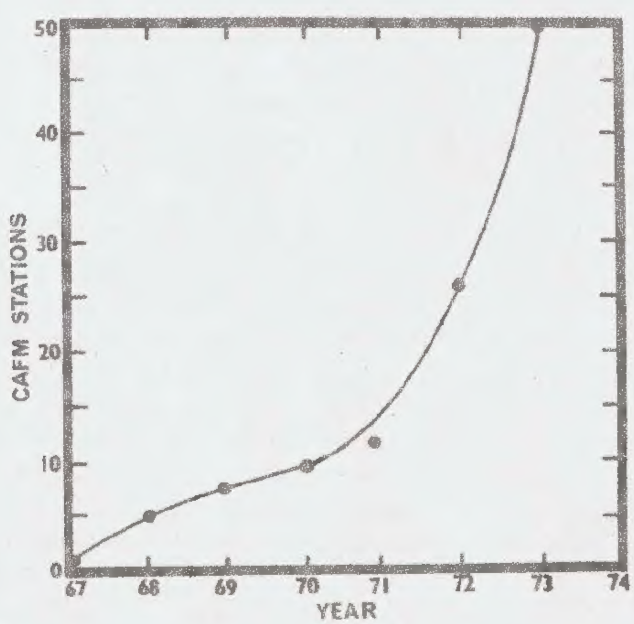
A number of intriguing uses for CAFM are popping up. The rebroadcasting of WWV, National Weather Service, police radio, and international shortwave programs are obvious. A few CATV systems are converting TV sound to FM frequencies, letting television viewers get high-fidelity sound for the first time. An explorer post in California is setting up a CAFM station. A symphonic orchestra in a major eastern city has its own CAFM outlet. Some cable operators are originating as many as seven channels of music. One western college, in addition to the campus station, uses a second CAFM channel for lectures and concerts. Perhaps the most intensive CAFM coverage of all is available in Bethlehem, Pa. There, Lehigh University's station WLRN operates carrier-current and mono CAFM, with WLVR on carrier-current, mono Class D FM, and stereo CAFM. Across town, Moravian College's WRMC also operates C-C and CAFM.

At least one manufacturer is producing equipment to take advantage of the

two-way "sub-band" feature found in some later cable systems. Where applicable, it works as follows: at the studio end, a monaural or stereo modulator operates in the 2-14 MHz range, feeding the "upstream" direction of the cable. At the head end, an up-converter translates the signal into the FM band for transmission downstream to the listeners. The total cost of the equipment is about $600 more than for a conventional system. Compared with renting 15 kHz audio lines at $30 per month, the sub-band system breaks even at about 20 months for mono and 11 months for stereo.

It appears that CAFM, as an emerging new medium, would make a good topic for studies and term papers in broadcasting or communications courses. A certain amount of survey research is possible, as by polling stations by mail. A lot of information helpful to the whole industry would emerge from a door-to-door survey of cable subscribers. Cable companies may be able to help listenership surveys by furnishing total numbers of FM taps and a sampling of names and addresses to be interviewed. A good, readable paper might convert readily into an article for the Journal of College Radio. And the topic certainly wouldn't appear unoriginal to instructors. The writer would be happy to provide considerable research material to anyone seriously studying the field.

The above article was written by Ludwell Sibley, Engineering Manager of the Intercollegiate Broadcasting System and a professional engineer with wide background in cable FM operations.



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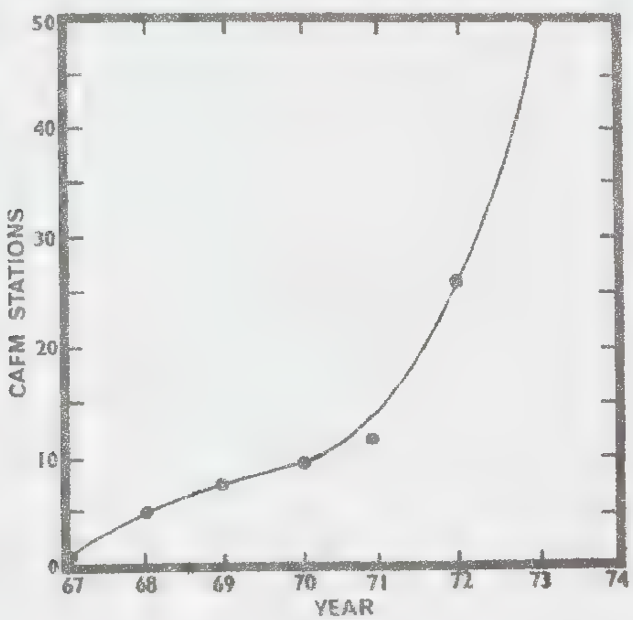

FIG. 1

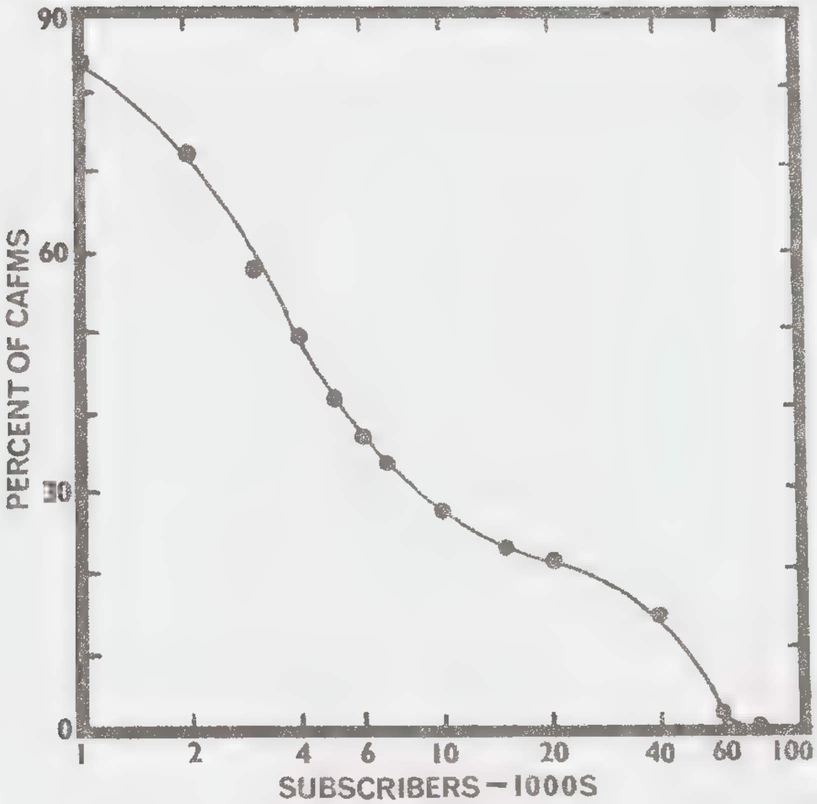
90
60
30
0
PERCENT OF CAFMS
1
2
4
6
10
20
40
60
100
SUBSCRIBERS — 1000S

FIG. 2

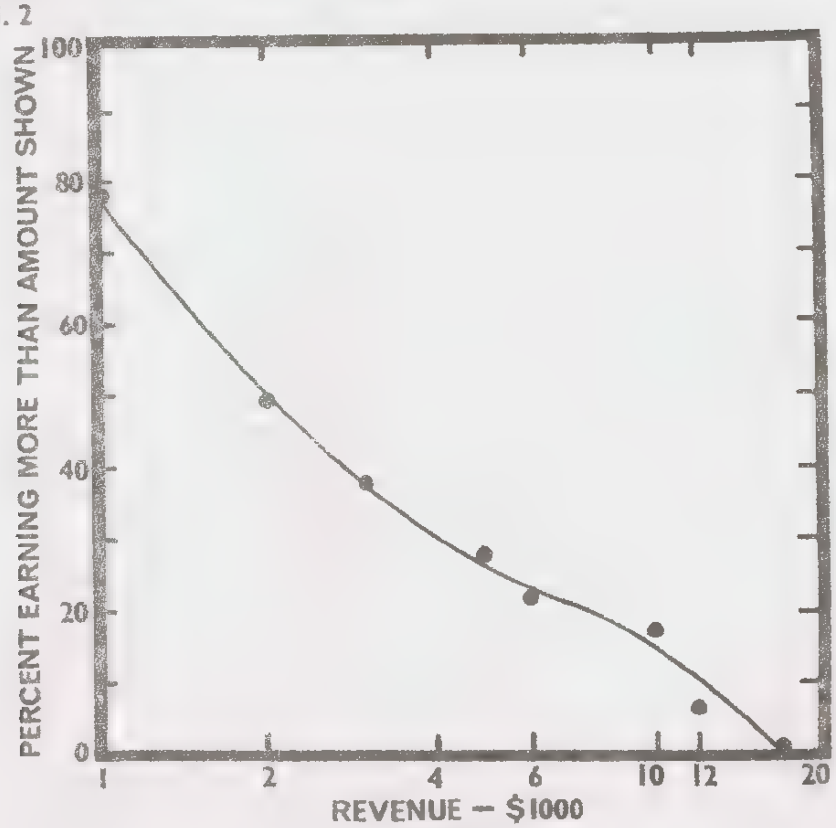
100
80
60
40
20
0
PERCENT EARNING MORE THAN AMOUNT SHOWN
1
2
4
6
10
12
20
REVENUE — $1000

FIG. 3

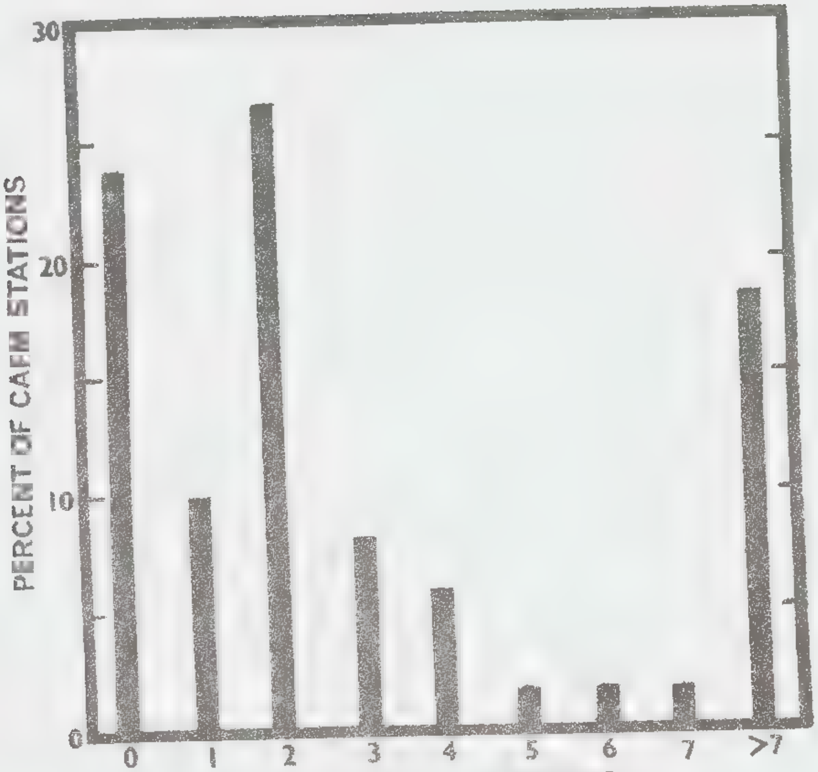
30
20
10
0
PERCENT OF CAFM STATIONS
0
1
2
3
4
5
6
7
>7
OTHER STATIONS

FIG.4

Proof of Performance

The FCC requires each broadcast licensee, except Class D FM stations, to run a proof of performance during the equipment test period, yearly thereafter, and within four months of application for relicense. No more than 14 months may elapse between successive proofs. The relevant Rules are 73.40 and 73.47 for AM stations, 73.254 and 73.317 for commercial FM, and 73.317 and 73.554 for educational FM.

IBS recommends that, as a matter of good engineering practice, Class D FM and cable FM stations also carry out a yearly proof of performance.

Most broadcast engineers use 8-1/2" x 11" binders for filing proofs. The first leaf is usually a title page. The second is an index, if the proof is long or complex. The required information is presented in graphic form wherever possible, with permissible limits shown on the same graph. For each series of measurements, a block diagram shows the equipment under test, the point of measurement, and the test instruments. The last page is usually the engineer's affidavit, which may or may not be notarized. The wording of the affidavit will be patterned after the engineering exhibits of FCC Forms 302 or 341, plus a brief resume of the engineer's qualifications. Keuffel and Esser No. 46 6882 "audio frequency" graph paper (20-20,000 Hz) is convenient for recording test results.

Test equipment for proofs of performance can usually be found in a college engineering laboratory. Most modern audio oscillators have distortion levels of -40 dB or better, which is satisfactory for FM use.

Distortion measurements can be made with either a tunable wave analyzer or a null-type analyzer. The former is slower to use and requires combining of the readings of each harmonic to obtain total harmonic distortion. However, it gives the information, useful for troubleshooting, of whether odd or even harmonics are predominant. Additionally, it is free from inaccuracy caused by noise. Null-type meters are available in inexpensive kit form, and, if equipped with VU-type ballistic response, can be used for noise measurement.

Noise measurement should be done with a meter rather than an oscilloscope. The latter tends to show impulse-type noise peaks which do not register on a VU-type meter, and which do not affect the human ear. The user should be careful to avoid ground loops which raise the reading on the noise meter. Excessive readings can also be the result of high-frequency noise or direct RF pickup. A simple RC filter will band-limit the noise meter to the 15 kHz required for FM, or 20 kHz for AM.

AN INTRODUCTION TO CARRIER-CURRENT RADIO

The term "carrier-current' originated with methods developed in the telephone industry around 1917 for sending several long-distance conversations at once over a single pair of wires. By the late Thirties the name had fallen into disuse in the telephone business, but had become a handy description for a method that appeared at several Eastern colleges for simulating radio transmission by applying an AM signal to the steam pipes, air ducts, or power wiring in dormitories. "Carrier-current," along with less popular titles ("powercasting," "wired wireless." "narrowcasting," 'wired radio," "limited area radio." and "closed-circuit radio"). came to be a general phrase for semi-formal broadcasting without need for an official license. The number of C-C stations in North America has now grown beyond 800.

Although college stations are the predominant user of C-C transmission, other applications exist. In the late Forties a few small towns were covered by C-C stations operated by local groups and churches trying to reach shut-in members. However, careless observance of the radiation regulations led to FCC action to shut down the offenders. An electrical engineer running for local office in New England in the early Sixties put together a C-C station, used it for campaign speeches, and won. There have been serious but unrealized proposals for a continent-wide broadcasting service using a radiating wire down the divider strip of interstate highways, and for specialized C-C coverage of urban ghetto areas. A semi-experimental licensed C-C station provides directions to motorists entering the Los Angeles International Airport. Various military bases, hospitals, drive-in churches (!), and commercial buildings use carrier-current for local coverage [1]. At least one conventional church uses a C-C transmitter to serve hard-of-hearing worshipers, who use transistor radios with earplugs [1]. There is even an unconfirmed report that C-C radio was used in wartime Germany to distribute programs to towns without providing a direction-finding source for approaching bombers [2].

There are numerous non-broadcast uses for carrier-current. Power companies use this technique in the 30-200 kHz band on high-voltage lines to derive as many as twenty simultaneous communication channels. [3]-[6], and telephone companies once served isolated farms by power-line carrier in the 150-410 kHz region [7], [8]. During World War II. with amateur radio operation suspended, some amateurs communicated around town by phone and CW, using carrier-current in the 150-200 kHz band [9]. Carrier-current intercom systems have been around since the Thirties [10], and a 300-kHz FM C-C arrangement has been tried for distributing background music throughout a building [11]. A variety of audio-frequency systems have been used or tried: 480- and 720- Hz tones to remote-control street lights and water heaters, used by the Springfield, Massachusetts power system as early as 1931 [12], 5200- and [illegible]-Hz tones to synchronize electric clocks throughout a large building, a present-day use, an experimental arrangement to link cash registers with a central computer file. A proposed nationwide emergency alarm network to supplant EBS proved infeasible only because a satisfactory tone-to-noise ratio was not obtainable at all receiving locations. These point-to-point services [illegible] receivers wired permanently to the line, whereas broadcast carrier-current assumes that the line radiates a small sign al into the receivers.

The FCC once felt that Class D FM broadcasting, with its relaxed equipment and operating requirements, would end the need for nonlicensed radio. However, C-C radio continued to grow. New Class D stations usually retain their C-C outlets to keep AM listeners and sell advertising. A favorite method for FM/C-C "simulcasting" is to feed normal programming into both systems until time for a commercial. At that point a two-track cartridge player puts a spot out on the C-C channel while feeding a public service announcement to the FM.

Carrier-current radio has the advantage of reaching a clearly defined audience whose program tastes and needs are far more predictable than those of the public at large. Thus an exceptionally high degree of service to that audience is possible. At one Midwestern school, there are even separate C-C stations for the dormitory and Greek areas of the campus. If the campus is covered by a coaxial-cable C-C network, the same cable can carry separate rock and classical stations simultaneously. Carrier-current and cable FM complement each other nicely for on- and off-campus coverage.

Carrier-Current and the Law

Carrier-current radio shares the AM spectrum with licensed broadcasters. The FCC and the Canadian Department of Communications regulate the use of radio frequencies. In hope of minimizing harmful interference, they have set stringent limits for the field strength emitted form nonlicensed radio sources. Part 15.7 of the FCC Rules [13] specifies that C-C transmitters must not radiate a field stronger than 15 microvolts per meter at a distance in feet from the power line defined by the quantity 157,000/(freq, kHz). Figure 1 shows this relation. (Radio field intensities are measured in quantities of millivolts per meter and microvolts per meter. A millivolt per meter is simply the electric field that would exist between two large metal plates, parallel and one meter apart, with a 1-mV generator connected to them. A standard broadcast station's primary coverage area involves two to ten millivolts per meter in residential areas. The 15-microvolt per meter limit on C-C

[illegible]

... LPb [illegible] Company, the matter has [illegible]

Carrier-current regulations in Can[illegible] are more stringent than in the U.S. [illegible] were instituted in 1971 un[illegible] [illegible] Broadcast Consultants No [illegible] [illegible] Technical Certification Requ[illegible]ments for Limited Area Broadcasting [illegible] Current System) in the AM [illegible]. The Department of Communi[illegible] requires noninterference [illegible] [illegible] radio and observance of the [illegible] of 15 uV/m at the 157,000/f [illegible]. The prospective C-C operat[illegible] [illegible] the Department of [illegible] [illegible] transmitter location [illegible] Field intensity measure[illegible] must be made at twelve de[illegible] [illegible] with respect to the building [illegible] [illegible] with the Department [illegible] [illegible] walkway lighting [illegible] power [illegible] [illegible]

[illegible]

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[illegible]

High Voltage Power Lines", *Bell System Technical Journal*, Vol. IV (1925), pp 152-177.

[4] "Power Line Carrier Systems", in D. H. Hamsher, ed., *Communication System Engineering Handbook*, McGraw-Hill, 1976, pp.14-1 to 14-25.

[5] "Carrier-Current", in A. E. Knowlton, ed., *Standard Handbook for Electrical Engineers*, McGraw-Hill, 1949, pp. 2124-2188.

[6] *Lynch Communication Systems, Inc* "Power Line Carrier System B950", catalog page 1035, San Francisco, 1968

[7] R. K. Honaman, "Rural Telephone Service over Power Wires", *Electrical World*, Vol. 124, No. 5 (4 August 1945), pp. 94-97

[8] "General Agreement for Power Line Carrier Facilities", Rural Electrification Administration Form 262, March, 1956.

[9] "Carrier-Current Communication", in *The Radio Amateur's Handbook*, 1945 ed., American Radio Relay League, West Hartford, Connecticut, 1944 pp 400-407.

[10] U.S. Patents 2,114,718 (Levy, 19 April 1938), 2,143,563 (Levy, 10 January 1939), 2,263,633 (Koch, 25 November 1941), 2,497,592 (Erickson, 14 February 1950), 2,632,812 (Cooney, 24 March 1953).

[11] "FM Carrier-Current Transmitter for Music Distribution" and "FM Carrier-Current Receiver for Music Distribution", *Essential Characteristics - Receiving Tubes*, 10th ed., General Electric Co. 1965, pp 284-287

[12] "40 Years Ago", *Electronics*, 27 March 1972, p 8

[13] "General Requirement for Restricted Radiation Devices" in Radio Frequency Devices, Part 15, *FCC Rules and Regulations* Vol II

[14] "Underground Radio", *Alternative Radio Exchange* Issue 13/14, 12 July 1972, p. 11

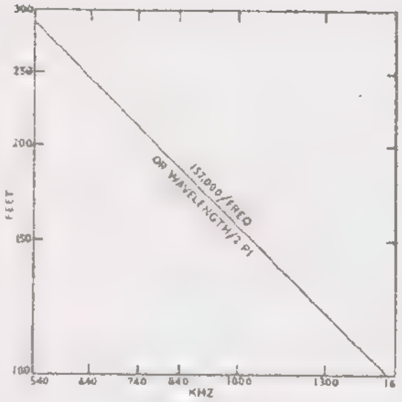


FIGURE 1

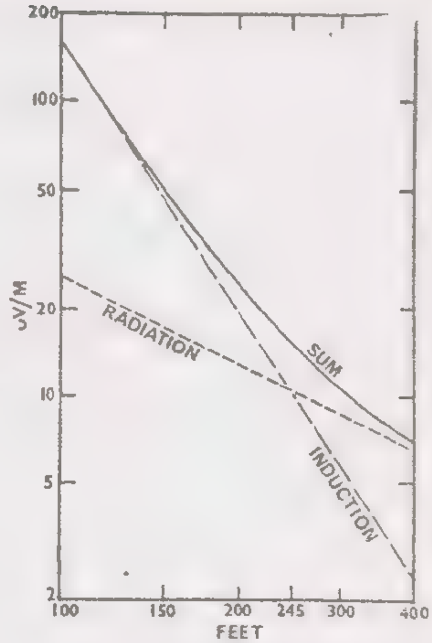


FIGURE 2

AM Channel Designations

The table below lists AM channels and their classes as designated under the North American Regional Broadcasting Agreement. It will be helpful, in conjunction with the IBS Engineering Code (50.90) and the information in 52.00, in choosing a channel for carrier-current use. In the case of Class I frequencies, the dominant station is shown.

kHz	Class	kHz	Class
530	*	760	U.S. I-A (WJR, Detroit)
540	Canadian I-A (CBK, Regina)	770	U.S. I-A (WABC, New York)
550-630	Regional	780	U.S. I-A (WBBM, Chicago)
640	U.S. I-A (KFI, Los Angeles)	790	Regional
650	U.S. I-A (WSM, Nashville)	800	Mexican I (XELO, Cd. Juarez)
660	U.S. I-A (WNBC, New York)	810	U.S. I-B (WGY, Schenectady)
670	U.S. I-A (WMAQ, Chicago)	820	U.S. I-A (WBAP, Ft. Worth)
680	U.S. I-B (KNBR, San Francisco)	830	U.S. I-A (WCCO, Minneapolis)
690	Canadian I (CBF, Montreal)	840	U.S. I-A (WHAS, Louisville)
700	U.S. I-A (WLW, Cincinnati)	850	U.S. I-B (KOA, Denver)
710	U.S. I-B (WOR, New York)	860	Canadian I (CJBC, Toronto)
720	U.S. I-A (WGN, Chicago)	870	U.S. I-A (WWL, New Orleans)
730	Mexican I-A (XEX, Leon)	880	U.S. I-A (WCBS, New York)
740	Canadian I (CBL, Toronto)	890	U.S. I-A (WLS, Chicago)
750	U.S. I-A (WSB, Atlanta)	900	Mexican I (XEW, Mexico City)

* Not a broadcast channel as such, but proposed under FCC Docket 20509 for use with 10-watt transmitters for informing automobile drivers of travel conditions. Since 530 has little problem of broadcast interference, it should be considered for carrier-current use.

A Class I station is protected from interference on its own channel to the 500 uV/m 50%-of-the-time skywave contour, which extends to at least 600 miles from the transmitter. It is also protected on first-adjacent channels to the 500 uV/m groundwave contour, which typically extends (in the 540-900 kHz range) to 180 miles. See 50.90 for other protection requirements.

Attenuation Data for RF Distribution Systems

RF Transformers and Power-Line Couplers - Typical Losses

Old-style tuned-circuit coupler, 2 links on 3" dia. air-core coil, tuned to resonance - 2.0 dB

Ferrite-core transformers
- On 3" x 5/8" rod core, untuned 1.0 dB
- On 1-1/4" toroid core, untuned 0.6 dB
- On toroid core, tuned (see 58.10) 0.4 dB

Coaxial Lines

Line	Loss @ 640 kHz (dB/100 ft)	Characteristic Impedance (ohms)
RG-174	0.96*	50
RG-58C	0.35	50
RG-59B	0.28*	75
RG-62A & 71B	0.23*	93
RG-11A & 13A	0.17	75
RG-8A & 213	0.17	52
RG-17A	0.06	52
.375 air-type	0.06	75
.480 CATV foam-type	0.06	75
.650 CATV foam-type	0.05	75
.750 CATV foam-type	0.04	75
.870 CATV foam-type	0.033	75

* This value is optimistic. The copper-plated center wire has high skin resistance at broadcast frequencies, probably giving higher loss than that shown.

Paired Lines

Line	Loss @ 640 kHz (dB/100 ft)	Characteristic Impedance (ohms, @ 640 kHz)
22-ga shielded pair	1.35	91
Telephone drop wire	1.2 (dry)	92
WD-1 field wire	1.2 (dry)	120
26-ga tel. cable*	0.70	99
24-ga tel. cable*	0.52	107
22-ga tel. cable*	0.44	91
19-ga tel. cable*	0.33	87
16-ga tel. cable*	0.22	85
16-ga video pair	0.142	127
Shielded twin-lead	0.30	300
"Spiral-four" field cable	0.50	124
WC-534 field cable (19-ga)	0.42	92
C Rural (telephone) wire	0.17 (dry)	118

* 0.083 uF/mi.

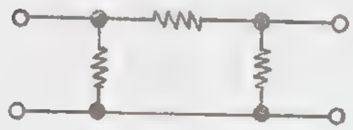
Note: unshielded lines are not recommended for outdoor use because of danger of radiation. These lines must have balanced terminations. Shields should be grounded about every 250 feet.

For frequencies other than 640 kHz, multiply cable loss figures shown by $(\text{new freq, kHz}/640)^{\frac{1}{2}}$. Fore example, for 530 kHz the multiplier is $(530/640)^{\frac{1}{2}}$ or 0.91.

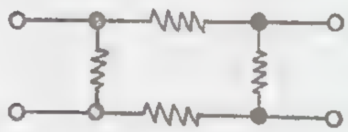
Pads and Bridges

Pads (attenuators) are used universally for adding fixed amounts of loss, matching impedances, isolating sources and loads, and related purposes. Bridges are a simple way to combine several sources into one line, or to distribute a signal to several independent outlets.

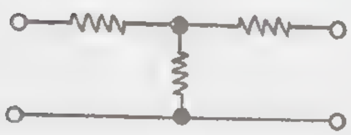
A. Pads. These take several forms:



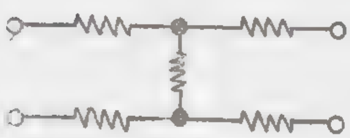
π A simple unbalanced device.



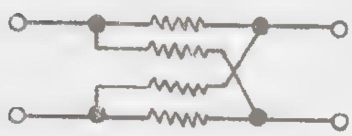
O Balanced version of the π-pad.



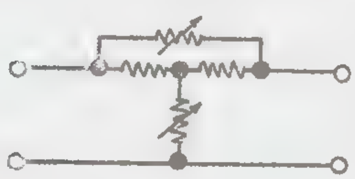
T Equivalent to the π-type electrically, but slightly less convenient to build because it takes an extra tie point.



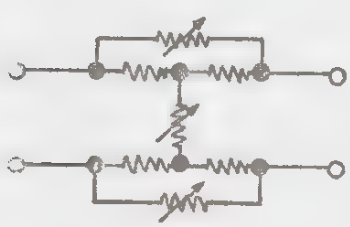
H Balanced version of the T-pad. Equivalent to the O-pad but takes one extra resistor and two more tie points.



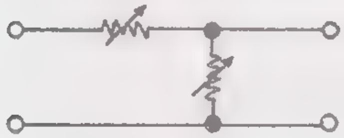
Lattice Equivalent to the O-pad. Convenient for specialized purposes like making patch cords with built-in pads, since the bodies of the resistors all lie parallel. Has no unbalanced equivalent.



Bridged-T A variant of the "T" used in variable attenuators. Two resistors are fixed while the other two are variable.



Bridged-H Balanced version of the bridged-T, also used in attenuators.



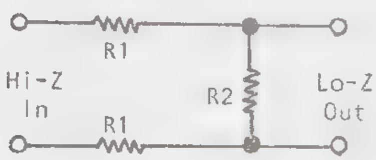
L An adaptation of the T-type, used for matching a high impedance on the left side to a lower impedance on the right. Also used for speaker volume controls not requiring constant impedance.

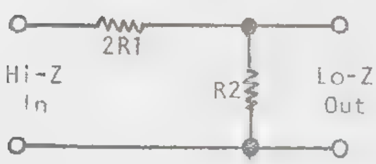
Table A gives the resistor values for building the common types of pads. It assumes input and output impedances of 600 ohms. For other impedances, the values all scale directly. For example, for 1200-ohm use simply double all the resistors.

Values in Table A are given to four decimal places, but the closest-value 10%-tolerance resistor will usually suffice. For greater precision, use of resistors with 5% tolerance will give not only tighter tolerances but twice as many standard values to choose from, like 110, 130, 160, 200, 240, etc., ohms. For further precision one can use 1% resistors or, cheaper and even better, use 10% resistors specially selected with a digital ohmmeter.

The errors from using 10% or 5% resistors are examplified by Table B. The losses are as calculated for a π-pad with 600-ohm terminations, assuming (a) use of the nearest standard value, and (b) that each resistor is at the end of its tolerance range that gives highest loss.

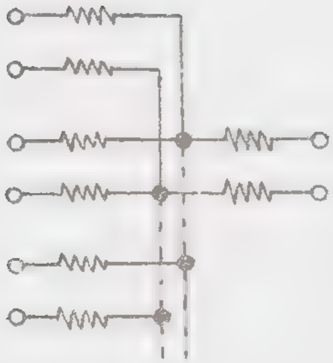
B. Minimum-Loss Impedance-Matching Pads. These are used to match a high-impedance source to a low-impedance load without using a transformer. The price, of course, is a fairly large transmission loss. Table C gives the resistors for a balanced matching pad for 600-ohm input and various load impedances. For an unbalanced pad, simply double R1. For comparison purposes, the table also shows the loss that occurs when the source and load are simply connected together without regard to mismatch. This is often permissible in audio circuits when the source and load contain resistive elements or very large coupling capacitors.

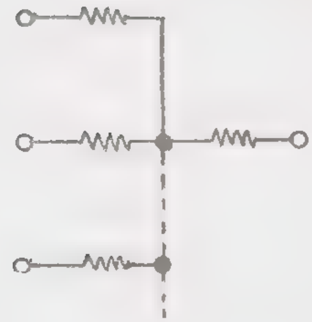




For other input impedances the resistors scale directly. For example, a 300:150 ohm pad uses half the resistance shown. The impedance ratio is 2:1, so the loss is 7.7 dB.

C. Bridges or Mixer Networks. These connect several inputs to one output, or vice versa, while giving correct impedance on all legs. The price of this impedance match is relatively high loss.





Resistor values for a balanced bridge, and the resulting loss, are shown in Table D. For an impedance other than 600 ohms, scale the values directly - for 150 ohms, use 1/4 the values shown. For unbalanced bridges, double the resistance.

Since a bridge is used to feed several cable pairs - either within the station or nonequalized telephone lines without transformers between the bridge and the cable - it is important to match the two resistors of each output closely to get good longitudinal balance (good common-made rejection). Otherwise crosstalk will occur within the cable, bad enough by itself but aggravated by having several pairs carrying the same outgoing signal. The resistors should be balanced to less than 1%, preferably by using a digital ohmmeter and selecting pairs. (The pair for one outlet may differ from the pair for another - Outlet 1 might use 178 and 179 ohms, Outlet 2 might have 186 and 187, and so on.) If balanced resistor pairs are not obtainable, a transformer should be used on each outlet that feeds cable to assure balance.

On bridges of this type, unused outlets should be terminated in resistors to prevent variations in level and impedance on the working legs.

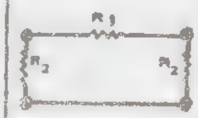
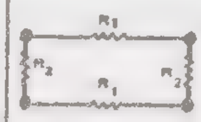
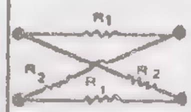
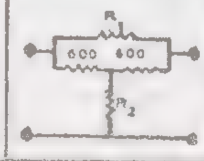
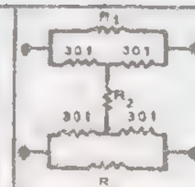
														
LOSS DB	R_1 OHMS	R_2 OHMS	R_1 OHMS	R_2 OHMS	R_1 OHMS	R_2 OHMS	R_1 OHMS	R_2 OHMS	R_1 OHMS	R_2 OHMS	R_1 OHMS	R_2 OHMS	R_1 OHMS	R_2 OHMS
0	0	00	0	00	0	00	0	00	0	00	0	00	0	00
0.1	3.58	[illegible]	1.79	50204	7.20	100500	3.66	100500	3.58	100500	7.2	[illegible]	3.6	50000
0.2	6.82	[illegible]	3.41	[illegible]	13.70	[illegible]	6.85	[illegible]	6.82	[illegible]	13.8	[illegible]	6.9	[illegible]
0.3	10.32	[illegible]	5.16	17460	20.55	[illegible]	10.28	34900	10.32	34900	21.0	17143	10.5	17143
0.4	13.79	10068	6.90	[illegible]	27.6	[illegible]	13.8	[illegible]	13.79	26100	28.2	12766	14.1	12766
0.5	17.20	[illegible]	8.00	10454	34.40	[illegible]	17.20	[illegible]	[illegible]	[illegible]	35.4	10169	17.7	10169
0.6	20.9	[illegible]	[illegible]	[illegible]	41.7	[illegible]	20.85	[illegible]	20.9	[illegible]	43.2	8333	21.6	8333
0.7	24.2	7428	12.1	7429	[illegible]	14380	24.25	[illegible]	24.2	14880	50.4	7143	25.2	7143
0.8	27.5	[illegible]	[illegible]	[illegible]	55.05	[illegible]	27.53	13100	27.5	13100	57.6	6250	28.8	6250
0.9	31.02	5787	15.51	[illegible]	62.3	11630	31.2	11600	31.02	11600	65.4	5504	32.7	5504
1.0	34.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	34.3	[illegible]	34.5	[illegible]	73.2	[illegible]	36.6	[illegible]
1.5	51.8	[illegible]	[illegible]	[illegible]	104.3	[illegible]	52.1	[illegible]	51.8	6950	113.4	[illegible]	[illegible]	3174
2.0	68.3	[illegible]	34.4	[illegible]	139.4	[illegible]	69.7	[illegible]	68.8	5232	155.4	[illegible]	77.7	[illegible]
2.5	[illegible]	[illegible]	42.9	[illegible]	175.4	[illegible]	87.7	[illegible]	[illegible]	4105	200.4	[illegible]	100.2	[illegible]
3.0	102.7	[illegible]	51.3	[illegible]	[illegible]	[illegible]	106.2	[illegible]	[illegible]	3505	247.8	[illegible]	[illegible]	[illegible]
3.5	119.2	[illegible]	[illegible]	[illegible]	258.0	[illegible]	129.0	[illegible]	[illegible]	[illegible]	297.6	[illegible]	[illegible]	[illegible]
4.0	135.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	143.8	[illegible]	[illegible]	[illegible]	354.0	[illegible]	[illegible]	[illegible]
4.5	152.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	162.3	2365	152.2	[illegible]	407.4	[illegible]	[illegible]	[illegible]
5.0	168.1	[illegible]	84.1	[illegible]	[illegible]	[illegible]	182.3	2141	168.1	2111	466.8	[illegible]	[illegible]	[illegible]
5.5	184.0	[illegible]	92.0	[illegible]	[illegible]	[illegible]	203.0	[illegible]	[illegible]	[illegible]	530.4	678.7	[illegible]	[illegible]
6.0	199.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	223.8	1807	[illegible]	1807	597.0	[illegible]	[illegible]	[illegible]
6.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	246.3	[illegible]	[illegible]	1679	667.8	[illegible]	[illegible]	539.8
7.0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	268.5	[illegible]	229.7	[illegible]	743.4	[illegible]	[illegible]	[illegible]
7.5	[illegible]	[illegible]	122	[illegible]	[illegible]	1475	292.4	1475	[illegible]	1475	[illegible]	[illegible]	371.7	437.6
8.0	258.1	[illegible]	[illegible]	[illegible]	[illegible]	1393	317.1	1393	258.4	1393	[illegible]	[illegible]	[illegible]	[illegible]
8.5	272.3	[illegible]	[illegible]	[illegible]	685.5	1322	342.8	1322	[illegible]	1332	[illegible]	396.[illegible]	[illegible]	[illegible]
9.0	285.8	[illegible]	[illegible]	[illegible]	731.9	1260	369.4	1260	285.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
9.5	298.9	[illegible]	[illegible]	[illegible]	794.4	[illegible]	397.2	1204	298.9	[illegible]	1091	[illegible]	[illegible]	[illegible]
10.0	312.0	[illegible]	156.0	[illegible]	854.1	1154	427.0	[illegible]	312.0	[illegible]	1191	302.2	[illegible]	[illegible]
11.0	336.1	[illegible]	168.1	[illegible]	[illegible]	1071	489.9	1071	336.1	1071	1297	[illegible]	764.5	[illegible]
12.0	359.1	[illegible]	179.5	[illegible]	1119	1002	559.5	1002	359.1	1002	1520	235.5	894	235.5
13.0	380.5	[illegible]	190.3	[illegible]	1273	945.1	636.3	945.1	380.5	[illegible]	1788	[illegible]	1040	[illegible]
14.0	400.4	[illegible]	200.2	[illegible]	1143	[illegible]	721.5	[illegible]	400.4	[illegible]	2080	[illegible]	1204	[illegible]
15.0	418.8	220.4	209.4	[illegible]	[illegible]	[illegible]	816.0	859.6	418.8	[illegible]	2407	[illegible]	1387	[illegible]
16.0	435.8	195.1	217.9	[illegible]	1347	826.0	923.2	826.0	435.8	826.0	2773	129.8	1598	129.8
17.0	451.5	172.9	225.7	[illegible]	2083	797.3	1042	797.3	451.5	797.3	3136	113.0	1824	113.0
18.0	465.8	152.5	[illegible]	[illegible]	2344	772.8	1172	772.8	465.8	772.8	3648	98.68	2083	98.68
19.0	479.0	[illegible]	239.5	[illegible]	2670	751.7	1635	751.7	479.0	751.7	4166	86.4	2374	86.4
20.0	490.4	121.2	245.2	121.2	2970	733.3	1485	733.3	490.4	733.3	4748	75.9	2700	75.8
22.0	511.7	95.9	255.9	95.9	3753	703.6	1877	703.6	511.7	703.6	5400	66.66	3477	66.66
24.0	528.8	76.0	264.4	76.0	4737	680.8	2369	680.8	528.8	680.8	6954	51.72	4455	51.72
26.0	542.7	60.3	271.4	60.3	5985	663.4	2992	663.4	542.7	663.4	8910	40.4	5685	40.4
28.0	554.1	47.8	277.0	47.8	7550	649.7	3775	649.7	554.1	649.7	11370	31.66	7236	31.66
30.0	563.0	37.99	281.6	37.99	9500	639.2	4750	639.2	563.2	639.2	14472	24.87	9186	24.87
32.0	570.6	30.16	285.3	30.16	11930	630.9	5967	630.9	570.6	630.9	18372	19.58	11643	19.58
34.0	576.5	23.95	288.3	23.95	15000	624.4	7500	624.4	576.5	624.4	23286	15.46	14736	15.46
36.0	581.1	18.98	290.6	18.98	18960	619.3	9480	619.3	581.1	619.3	29472	12.21	18630	12.21
38.0	585.1	15.11	292.5	15.11	23820	615.3	11910	615.3	585.1	615.3	37260	9.66	23529	9.66
40.0	588.1	12.00	294.1	12.00	30000	612.1	15000	612.1	588.1	612.1	47058	7.65	29700	7.65
											59400	6.06		6.05

TABLE A
RESISTOR VALUES FOR 600-OHM PADS

TABLE B

Pad Losses with High-Tolerance Resistors

Nominal Loss (dB)	Worst-Case Loss (dB) With 10% Resistors	Worst-Case Loss (dB) With 5% Resistors
3.0	3.5	3.2
6.0	6.8	6.2
12.0	13.5	12.5
24.0	25.5	24.7

TABLE C

Minimum-Loss Matching Pads - 600 Ohm Imput

Load (ohms)	Impedance Ratio	R1 (ohms)	R2 (ohms)	Pad Loss (dB)	Mismatch Loss (dB)
500	1.2	123	1224	3.8	0.04
400	1.5	173	694	5.7	0.2
300	2.0	212	425	7.7	0.5
200	3.0	245	245	10.0	1.2
150	4.0	260	173	11.4	1.9
120	5.0	269	134	12.5	2.6
100	6.0	274	109	13.4	3.1

TABLE D

Balanced Bridges

Inputs or Outputs	Resistors (ohms)	Loss (dB)
2	100	6.0
3	150	9.5
4	180	12.0
5	200	14.0
6	214	15.6
7	225	16.9
8	234	18.1
10	246	20.0
12	254	21.6
16	265	24.1
20	272	26.0

Measurement of Program Level: the Volume Unit and vu Meter

Measurement of the level of program audio is difficult because music and speech produce complex waveforms with irregular peaks. With speech especially, the positive and negative peaks may differ in voltage. Level measurement also requires a unit that tracks the actual volume as perceived by the listener.

To allow proper operation of studios, recorders, transcontinental networks, and transmitters, a standard measuring technique is essential. This need is met by the volume unit and volume-unit (vu) meter. Program level is thus measured in special units, on a unique meter, with a particular observation technique.

The standard vu meter has tightly specified characteristics. Its frequency response is ± 0.2 dB, 35-10,000 Hz; and ±0.5 dB, 25-16,000 Hz. Its dynamic or ballistic characteristics are quite definite: when pulsed with a sine wave corresponding to a "0 vu" reading, the meter must overshoot between 1% and 1.5%. The needle must reach 99% of the 0-vu reading within 0.3 second, and must withstand a constant overload of five times the voltage corresponding to the "zero" reading. It must not be sensitive to polarity of asymmetric peaks, i.e., it uses a full-wave rectifier. (Small meters labeled in vu are common in inexpensive recorders and home hi-fi equipment. It is not clear that these meters meet all the requirements for a true vu meter.)

Two standard scales are available. The "A" scale has "volume units" from -20 to 0 at about 71% of full scale, continuing to "+3" at full scale. There is a secondary percent scale, with 100% matching 0 vu, below. This scale is most common in test equipment and network monitoring meters. The "B" scale has the vu and percent scales reversed to emphasize modulation level, and is the usual scale for studio equipment.

As far as actual power measurement with a vu meter is concerned, the meter would read 0 vu if a test tone of 0 dBm (1 milliwatt) at 1000 Hz and 600 ohms were present. The level is the value of recurring peaks as read by mentally averaging the readings of the meter over a long period, typically a minute. One or two unusually high peaks in the test period are ignored.

The vu meter is bridged across the circuit being monitored, with its impedance built out to 7500 ohms. This holds harmonic distortion caused by the meter rectifier to 0.2% or less, and produces less than 0.4 dB of bridging loss. The 7500 ohms consists of the 300-ohm meter movement, a 3600-ohm internal resistor, and another 3600 ohms externally.

The meter itself reads "0" at a voltage corresponding to +4 dBm (1.228 V on the 600-ohm line, applied to the series combination of the meter and 3600-ohm resistor.) The voltage driving the meter circuit comes from the 600-ohm console paralleled by a 600-ohm load, or a source impedance of 300 ohms. See Figure 1.

Studio consoles, limiters, and compressors are normally designed to produce +8 dBm on peaks. So a 3900-ohm pad is wired into the meter circuit to make it read "0 vu" at an actual output of +8 dBm. Where the equipment feeds 600-ohm constant-impedance loads, a 4-dB 3900-ohm pad is used between the bridging resistor and the meter. Figure 2 shows the circuit.

Where the equipment feeds a program line (studio-transmitter link, say), a 6-dB isolating pad is normally included. Since the line impedance varies greatly with frequency, the pad keeps the variable load from upsetting the accuracy of the meter. The meter is being fed from a +14-vu source, so a 10-dB meter pad is necessary. See Figure 3.

By contrast, the vu meters on many professional tape recorders read "0 vu" at an output level of +4 dBm. Many older studio consoles have a variable attenuator in the meter circuit to select a variety of reference levels.

To build meter pads for any desired reference level, look up the resistor values for the desired pad (4 dB for "0" at +8 dBm, 20 dB for "0" at +24 dBm, etc.) in MH Section 53.14R. Multiply the resistances by 6.5 to produce a 3900-ohm pad. (The 3600-ohm resistor is normally provided by adding 3600 ohms to the input resistor of the pad.) A source impedance other than 3900 ohms would upset the controlled damping of the meter.

A traditional assumption is that the peak power of a +8-vu signal is +18 dBm. That is, instantaneous peaks go 10 dB higher than the meter reading. The line amplifier in the equipment is thus designed for a "headroom" of at least 10 dB. Unprocessed speech may have higher peaks. Peaks on music are generally less than 10 dB.

Because the meter uses a full-wave meter, assymetric speech waves will give different sensations of loudness for a given vu reading. For a given complex waveform, there is only a rough correlation between a vu meter and a half-wave quasi-peak meter such as is used in modulation monitors. Unless audio compression and/or limiting are used, speech levels with their narrow "spikes" must be "ridden" at a lower level than music to avoid overmodulation.

Because the vu meter has good frequency response, it is useful for measuring frequency response and other test functions. The FCC performance standards for FM radio (Section 73.317, which applies to both commercial and noncommercial stations) require vu-meter-type ballistic response for noise measurements. For power measurements, a vu meter can be made to read "0" when bridged across a 600-ohm line carrying 0 dBm (1 mW) by using no pad and changing the 3600-ohm bridging resistor to 842 ohms. The meter will then be slightly overdamped.

Very old broadcast equipment operated at a peak level of "0 dB," which was defined as 6 milliwatts (+7.8 dBm) in 500 ohms. Other levels were used also. Meters were generally calibrated in decibels, and did not have the ballistic characteristics of vu meters.

Other systems besides the vu meter exist for program loudness measurement. One "program voltage meter" used by the European Broadcasting Union is a peak-reading type with very fast attack time (about 10 ms) and slow decay (2 to 3 sec.). It is far more complex than the simple vu meter, but is claimed to give results less dependent on the characteristics of the program material. Use of the quasi-peak meter apparently gives an overall program level 4 to 5 dB higher than a vu meter would give on the same material, although use of limiting and compression may remove this advantage. Another claimed advantage of the European design is easier level-riding and reduced operator fatigue.

Another recently developed program meter uses a similar fast-attack/slow-decay circuit, but with LED indicators added to the meter to show peaks

of 0, +8, +12, +14, and "overload." The circuit delay times are adjustable to fit operator preferences. Its claimed advantages are like those of the EBU quasi-peak meter.

Both these new meters are substantially more expensive than the traditional vu meter.

In defense of the vu meter, it is necessary to point out that it was designed (as a joint effort of CBS, NBC, and the Bell System) for universal application, including use on long network lines. A peak-reading meter is subject to considerable error if delay distortion* is present. In such a case two network locations might see widely different peak readings on the same signal, caused by (inaudible) delay distortion. The relatively slow response time of the vu meter was apparently chosen because listeners cannot detect bursts of peak clipping shorter than a few dozen milliseconds. Thus a peak-reading meter may be best suited to local broadcast installations where no network operation is used.

* Different speed of transmission for high and low frequencies. Also called phase distortion.

References

1. American National Standards Institute, "American Standard Practice for Volume Measurements of Electrical Speech and Program Waves," ANSI C16.5-1954, Nov. 29, 1954 (printed in Proceedings of the I.R.E., Vol. 42, No. 5, May, 1954).

2. H. Schmid, "Audio Program Level, the VU Meter, and the Peak-Program Meter," IEEE Transactions on Broadcasting, March, 1977, pp. 22-26.

3. W. Hetrick, "The ACCU-PEAK™ Level Indicator," IEEE Transactions on Broadcasting, Sept., 1975, pp. 101-105.

4. Bell Telephone Laboratories, Inc., "Volume," *Transmission Systems for Communications*, 3rd Ed., Western Electric Co., 1964, pp. 19-21.

5. Catalog sheets produced by Simpson Electric Co., The Triplett Electrical Instrument Co., and Weston Instruments.

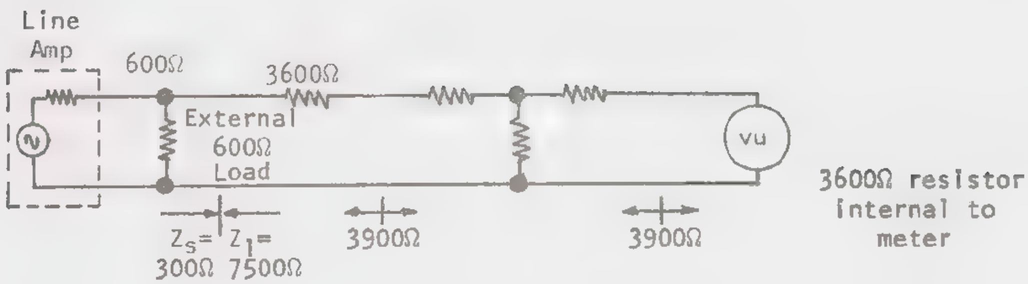


Figure 1. Equivalent Circuit Feeding vu Meter

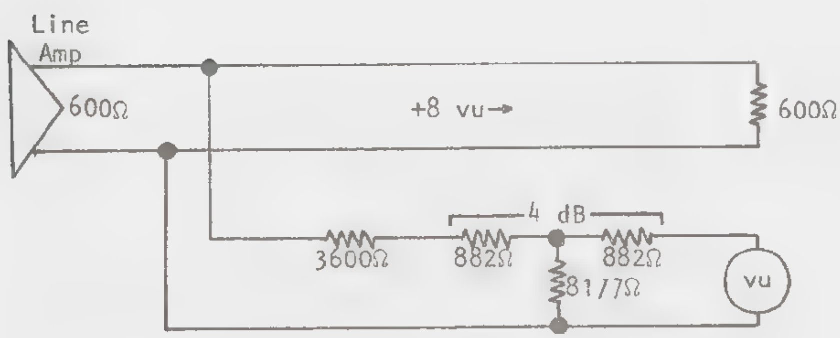


Figure 2. Meter Pad for 600Ω Constant-Impedance Load

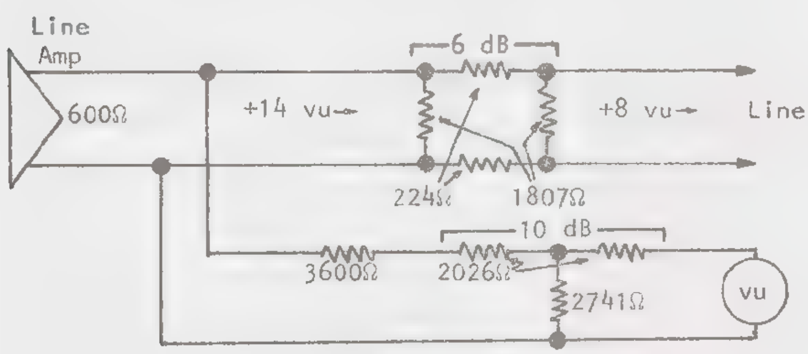


Figure 3. Output Circuit and Meter Pad for Program Line

MISCELLANEOUS REFERENCE DATA FOR ELECTRONIC CONSTRUCTION

ELECTROLYTIC CAPACITORS

Code for terminals on can-type capacitors:

⌓	Highest	In order of voltage first, then in order of capacitance.
□	Intermediate	
△	Lower	
▭	Lowest	

COLOR CODES - CABLE

Pair	Vinyl Audio Cable[1]			Polyethylene Telephone Cable[1]		
	Wires	Foil Shield		Ring		Tip
1	Bk - R	R		Bl	-	W
2	Bk - W	Gn	Inner	Or	-	W
3	Bk - Gn	Bl	Layer	Gn	-	W
4	Bk - Bl	R		Bn	-	W
5	Bk - Y	Gn		Sl	-	W
6	Bk - Bn	Bl		Bl	-	R
7	Bk - Or	Bl	Outer	Or	-	R
8	R - W	Bl	Layer[2]	Gn	-	R
9	R - Gn	Bl		Bn	-	R
10	R - Bl	Bl		Sl	-	R
11	R - Y	Bl		Bl	-	Bk
12	R - Bn			Or	-	Bk
13	R - Or			Gn	-	Bk
14	Gn - W			Bn	-	Bk
15	Gn - Bl			Sl	-	Bk
16	Gn - Y			Bl	-	Y
17	Gn - Bn			Or	-	Y
18	Gn - Or			Gn	-	Y
19	W - Bl			Bn	-	Y
20	W - Y			Sl	-	Y
21	W - Bn			Bl	-	V
22	W - Or			Or	-	V
23	Bl - Y			Gn	-	V
24	Bl - Bn			Bn	-	V
25	Bl - Or			Sl	-	V
26	Bn - Y			R	-	[illegible][3]
27	Bn - Or					

1. Abbreviations for colors are:

Bl = Blue	Bn = Brown	R = Red
Or = Orange	Sl = Slate	Bk = Black
Gn = Green	W = White	Y = Yellow
	V = Violet	

2. Pairs 6-11 can be located without breaking the shield by starting with the R and Gn shields in the outer layer and counting around the cable.

3. Used in older ("odd count") cables for the last (26th, 51st, etc.) pair. Cables larger than 25 pairs use 25-pair groups bound with Bl-Wh, Or-Wh, Gn-Wh, etc., strings.

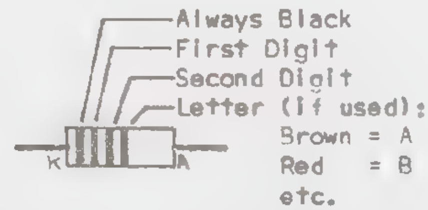
COLOR CODES - CHASSIS WIRING

Black - Grounds and returns
Brown - Tube heaters
Red - Power supply (B+)
Orange - Tube screens
Yellow - Emitters, sources, and cathodes
Green - Bases, gates, and grids
Blue - Collectors, drains, and plates
Gray - AC power lines
White - Above- or below-ground returns, AVC, etc.

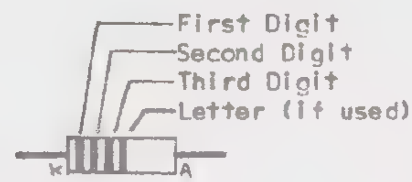
COLOR CODES - DIODES

Unidentified types

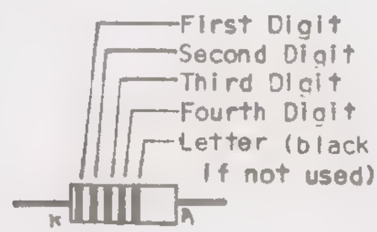
Two-digit types



Three-digit types



Four-digit types



FUSES

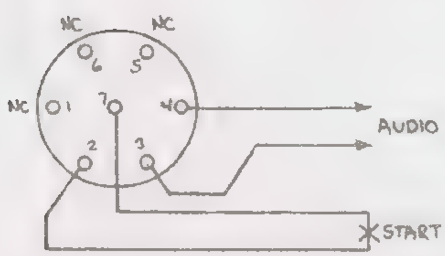
Resistances of standard 3AG fuses:

Rating (Amps)	Ohms	Rating (Amps)	Ohms	
1/16	6.35	4	0.049	
1/8	5.4	5	0.029	
1/4	3.27	6	0.025	
3/8	2.38	8	0.022	
1/2	1.39	5	0.028	32-volt types
3/4	0.89	7.5	0.020	32-volt types
1	0.23	10	0.011	32-volt types
1.5	0.146	15	0.008	32-volt types
2	0.073	20	0.006	32-volt types
3	0.052	30	0.005	32-volt types

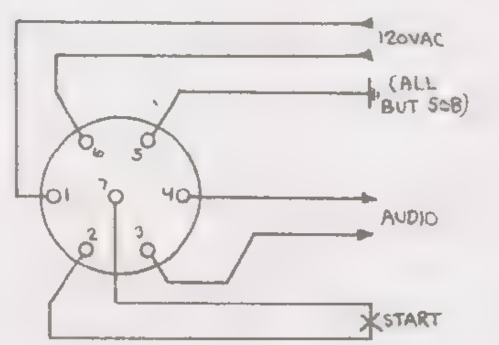
RECORDER CONNECTORS

Standard pin numbers for telephone company recorder connectors:

Voice Connecting Arrangement
RCZ (KS-19645);
Elgin Electronics ERC-19645-2



Tone Warning Generator 0-93/GT;
Automatic Electric Model 31;
50A, 50AA, 50B Recorder Connectors



Required plug is an ITT Cannon SK-M7-21C-1/2. Audio from the connector is balanced, nominally 600-ohm, but may be terminated in an unbalanced load. The START switch should be open at all times the connector is not being used; this prevents beeps from crosstalking into other circuits. See also MH 56.90

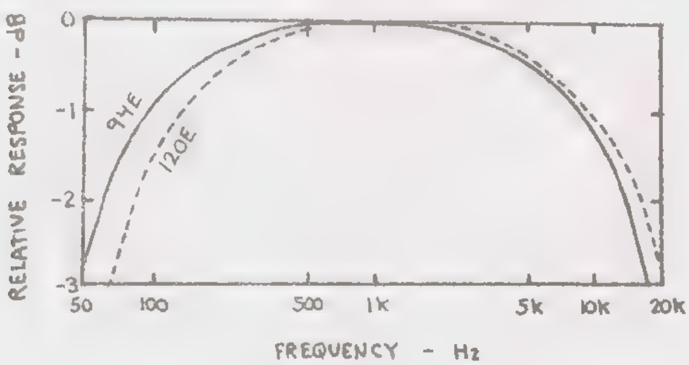
TELEPHONE REPEAT COILS

Western Electric Type	ADC Type	Nominal Ratio Primary:Secondary	Terminals Primary — Secondary	Nominal Response	Remarks
23A	109A	600 : 135	1-3/4-6 to 2-3/4-5	C	Autoformer
67A	118A	600 : 600	1-2/5-6 to 3-4/7-8	R	
93A	113A	600 : 600	"	R	Dual Unit
B	B	" 375	"	R	"
F	F	" 950	"	R	"
G	G	" 1500	"	R	"
H	H	" 750	"	R	"
J	J	" 1350	"	P	"
94E	109S	600 : 600	"	V	
F	T	900 : 600	"	V	
H	K	600 : 600	"	V	
J	U	30 : 60	1-2 to 4-5-6	V	
K	V		1-2 to 3-4	V	
L	W		"	20 Hz	
N	Y	600 : 600	As for 67A	V	
P	Z	10 : 25	1-2 to 7-8	V	5-6 is 25Ω res.
[illegible]	BA		1-2 to 3-4-5-6-7	1 kHz	
S	BB	27K : 30	As for 67A	1 kHz	
T	BC	600 : 400	As for 67A	V	
U	BD	20 : 600	1-2/3-4 to 5-6	V	
W	BE	1 : 1800	1-2 to 3-4/5-6	V	
Y	BF	600 : 600	1-2 to 3-4	V	
AA	BG	300 : 600	As for 67A	V	
111C	118F	600 : 600	"	B	
119C	S	600 : 600	"	B	
E	U	600 : 600	"	B	
F	Y	600 : 1200	"	B	
120C	109B	600 : 600	"	V	
D	C	900 : 600	"	V	
E	D	400 : 600	"	V	
F	E	360 : 900	"	V	
H	F	600 : 600	"	V	
J	G	900 : 600	"	V	
K	H	400 : 600	"	V	
L	P	360 : 900	"	V	
M	AM	600 : 200	As for 94U	V	
		600 : 12600	1-2/3-4 to 5-7	V	
N	AN		7-8/9-10 to 1-2/3-4/5-6	V	
P	AP		7-9/10-12 to 1-2/3-4/5-6	V	
146A	L	135 : 600	As for 67A	C	
U	M	600 : 600	"	C	
173B	CB	600 : 2000 + 2000	1-2/5-6 to 3-4/7-8 and 9-10/11-12	V	Hybrid
C	CC	600 : 2800 + 2800	"	V	"
D	CD	600 : 720 + 720	"	V	"
E	CE	600 : 1200 + 1200	"	V	
177C	119C	600 : 600	1-3/4-5 to 7-9/10-11	B	
D	D	600 : 150	"	V	
		600 : 600	1-2/3-4 to 6-8/9-11		
		600 : 1350	1-2/3-4 to 5-8/9-12		
[illegible]	112F	170 : 340	1-2/3-4 to 5-6-7	V	
[illegible]	J	600 : 600	As for 67A	V	

Nominal frequency response codes are

- V - Voice (200-3000 Hz)
- R - Ringthrough (20-3000 Hz)
- B - Broadcast (20-15000 Hz $\pm$ 1/2 dB)
- C - Carrier (0.2 to 50 kHz or higher)

Individual coils are usually better than their nominal ratings. The measured responses of a 94E and a 120E coil appear below.



It is believed that Automatic Electric 1200-series coils are equivalent to Western Electric 120-type. For example, a 1200C is probably the same as a 120C.

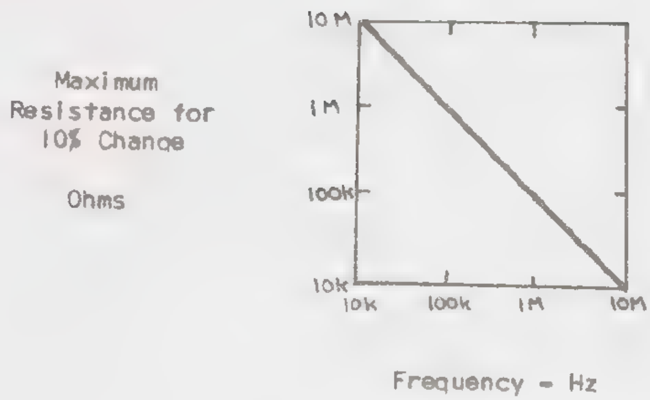
RESISTORS

Maximum Voltage Ratings

Wattage	Maximum Working Voltage
1/8	150
1/4	250
1/2	350
1	500
2	500

Change in Effective Resistance with Frequency

Because of skin effects, the resistance of composition resistors depends somewhat upon the frequency of operation. High values of resistance change the most. The graph below gives the maximum resistance for a 10 per cent change from the DC resistance.



All-carbon (low-valued) resistors are largely free from this effect below about 100 kHz.

MISCELLANEOUS STANDARDS

Telephone Lines:

Ring lead is the
- Right wire or terminal.
- Ridged side on drop wire.
- Red lead on station wire.
- Negative wire with respect to ground.

Tip lead is the
- Top wire on terminals.
- Positive lead with respect to ground.

Stereo Pickup Leads:

Number of Leads	Right Channel High	Right Channel Low	Left Channel High	Left Channel Low	Ground
3	R	-	W	-	Bk
4	R	Gn	W	Bl	-
5	R	Gn	W	Bl	Bk

Standard load impedance is 47 K in parallel with 275 pF.

Stereo Headphones:

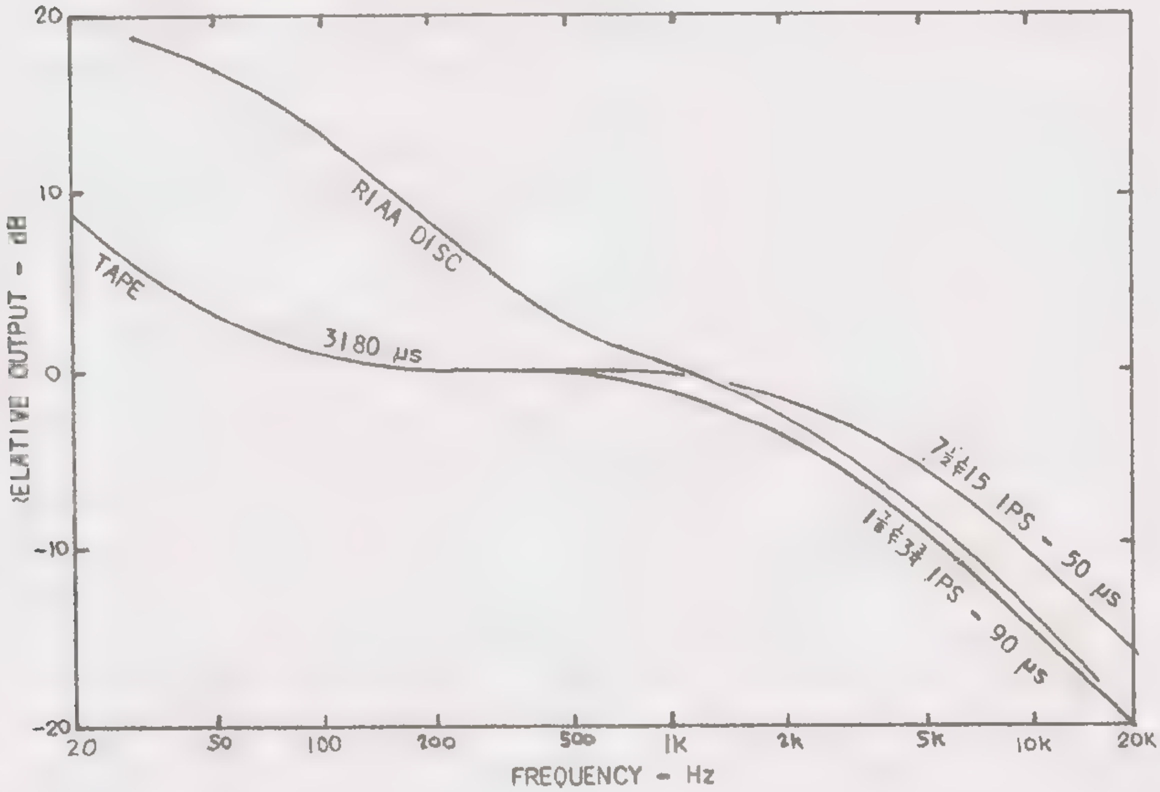
Left is ring, Right is tip, Common is sleeve.

Microphones:

In-phase is red or 1, out-of-phase is black or 2.

STANDARD PLAYBACK PREAMPLIFIER RESPONSE — RIAA DISC AND NAB TAPE

For FM preemphasis curve, see MH 62.05.



Standard Speaker Mounting Data

Size	Typical Baffle Hole	Mounting Holes
3-1/2"	3-1/8"	4
4	3-3/4	4
5	4-1/8	8
5-3/4	4-3/4	8
6-1/2	5-3/8	8
8	6-3/4	8
10	8-3/4	4
12	10-3/4	4
15	13-1/4	8

Shunt Resistors for Milliammeters

Full Scale (mA)	Shunt (ohms)
For 1-mA (27 ohm) meter	
10	3.0
50	0.551
100	0.272
500	0.0541
For 1.5-mA (35-ohm) meter	
15	3.89
75	0.714
150	0.354
750	0.0701

Dry Battery Capacities - Standard Zinc-Carbon Cells

For Size D cells, discharged at constant current to 1.13 volts, used 5 hr/da and 5 da/wk:

Current (mA)	Capacity (A-hr)
3	4.1*
5	4.9*
10	5.6
30	3.25
50	1.70

* Affected by shelf life.

Maximum Capacities

Size	Dimensions	Current (mA)	Hours	Capacity#
AAA	1/2" x 1"	3	110	.33
A	5/8 x 1-7/8	5	230	1.15
B	3/4 x 2-1/8	8	220	1.76
D	1-1/4 x 2-1/4	10	540	5.40
F	1-1/4 x 3-1/2	-	-	-
G	1-1/4 x 4	15	780	11.7

Ampere-hours to 1.13 V.

Electrical Wiring Requirements (1978 National Electrical Code)

	Rating-Amperes*	
Wire Size	Types T & TW	Types RH, RHW, & THW
14	15	15
12	20	20
10	30	30
8	40	45

* In conduit, in cable, or direct-buried, for copper wire.

Required Size of Conduit - Typical

	Wires to Be Installed				
Wire Size*	2	3	4	5	6
14	1/2	1/2	1/2	1/2	1/2
12	1/2	1/2	1/2	1/2	1/2
10	1/2	1/2	1/2	1/2	3/4
8	1/2	3/4	3/4	1	1

* For T and TW wire.

Extending the Life of Vacuum-Tube Equipment

The Problem. In the present era it's almost embarrassing to talk about vacuum tubes. But there are still great numbers of good tube recorders, consoles, transmitters, and test instruments in broadcast use. Stations with limited budgets have to get maximum use out of what they have. The same stations can expect donations of used tube equipment from commercial stations in the future. So it should be helpful to list ways to preserve the usefulness of this older gear.

Replacement tubes are getting hard to find. One major electronics distributor whose catalog listed [illegible] types six years ago now lists only 287. Where tubes are still available, their prices are rising fast. The cost of a typical order for seven types used in [illegible] stations - one 6AQ5, 6CA7, 6L6GC, [illegible], 5R4, [illegible], and [illegible] has risen 15% per year for the last five years.

Updating. A station with tube equipment can modernize its gear to some extent. Tube rectifiers are easy to convert. On an ordinary full-wave rectifier, use two strings of silicon diodes. The total peak-reverse-voltage rating of each string must be at least 3.14 times the DC output voltage. A safety factor of two above this minimum is strongly recommended. Wire a 100-kilohm resistor across each diode to give all units the same reverse voltage. Otherwise the diode with highest back resistance will receive most of the voltage and will fail. Cheap unmarked diodes (factory rejects) sold in bulk work fine, but check their polarity - out of one bag of 100, a third had the polarity marking molded into the case backward.

On bridge rectifiers used in transmitters, each diode string need be rated for only 1.57 times the output voltage, with a safety factor of two or three recommended. For those who prefer not to build their own diode strings, packaged plug-in replacements are available.

A tube power supply converted to solid-state usually gives about 20 extra volts. To reduce the voltage to normal, rewire the input capacitor in the filter to the output, giving a [illegible] filter. Or wire the former rectifier-filament winding of the transformer in series with the primary winding, poled to give [illegible].

[illegible] diodes, like [illegible] in audio compressors and limiters, require more consideration. The conduction curves for tube and solid-state diodes are somewhat different. The tube conducts even when slightly back biased, but [illegible] conduct well until forward-biased by [illegible] for silicon. This difference often does not matter. If it does, germanium diodes are preferred [illegible] devices are better yet. [illegible] it may be necessary to add a bias resistor to contribute a small amount of forward bias.

Gas regulator tubes are easy to replace. The octal ones (OA3, OB3, OC3, OD3) can be changed to zener diodes rated at 75, 90, 105, or 150 V and 3 to 6 W respectively. The miniature regulators (5651, OB2/OC2, OA2) take diodes of [illegible] respectively, at 0.5, 3, or 5 W. (Zeners rated for less power can often be used if the power at which the tube actually operates is measured or calculated.) In the usual case where a positive voltage is being regulated, "reversed" zeners with anode connected to the mounting stud can be bolted directly to the chassis.

Triode and pentode voltage amplifiers operating at low power can be converted to operation with field-effect transistors, since a FET acts much like a triode. The accompanying figure shows three useful circuits: direct

replacement of a triode, a basic cascade connection to replace a pentode using a high-voltage-rated FET, and a more complex pentode replacement using lower-voltage but cheaper units.

As the above implies, in a converted amplifier one must either reduce the "plate" voltage to meet the rating of the FET or use a high-voltage device. The existing cathode resistor usually gives the right bias voltage. Unused tube leads (heater, screen, suppressor) are simply ignored. For pentodes used in some oscillator circuits, electron-coupled for instance, it is necessary to add a resistor and capacitor in parallel between the old plate and screen leads to give the necessary feedback path.

The converted amplifier, of course, has no microphonics or heater-induced hum. Converted pentode preamplifiers can easily be quieter than the original version.

For reference and substitution purposes, Table A gives principal characteristics of the transistors, which are N-channel JFETs.

Plug-in FET replacements for tubes like the 6AK5, 12AX7, and 12AT7, and complete kits for certain Hewlett-Packard instruments, are available from Teledyne. Heath sells a pair of plug-ins (12AU7 and 6AL5) for its vacuum-tube voltmeters, turning them into instant FET-VOMs.

Tube Substitutions. There is no replacement in sight for higher-power tubes. This is a serious matter, considering the number of tube carrier-current and FM transmitters with years of service life left.

Of particular concern is the 7984 tube used in 20-watt C-C transmitters. This is a "compactron" made only, as far as is known, by General Electric. It was used in GE mobile radios in production as recently as about 1974 and is still available. If it becomes unobtainable, the 6146B is a natural choice as a replacement. It was used in earlier C-C transmitter models, with the only significant circuit difference being use of a 15-kilohn 5-watt screen resistor. It will require a change of socket and rewiring of the heater leads to give 6 volts. The 6146B is widely used in commercial transmitters, hence will probably remain available relatively long. Its only drawback is that, at the relatively low plate voltage used in C-C equipment, it may not modulate as fully as the 7984.

The 6CA7/EL34 tube in many C-C transmitters is becoming scarce. The 6L6GC should be a satisfactory replacement without rewiring.

The 6AL11, also common in C-C gear, will probably become rare eventually, particularly since RCA in no longer a second-source maker. For earlier transmitters not using printed-circuit construction, an emergency measure would be to use a 6AU6 and a 6AQ5 to replace the pentode and tetrode halves of the 6AL11 respectively. This would require changing one 12-pin socket to two 7-pin ones.

The replacements suggested above are still widely available and are fairly similar to the originals. They have higher dissipation ratings.

If the equipment in question is FCC type-accepted (for example, FM transmitters and stereo modulation monitors), Parts 2.932 and 2.1001 of the Rules describe the limitations on modifications. Basically, a user may make minor changes as long as they do not degrade performance below levels reported to the Commission in the original type-acceptance filing.

Coding Systems for Tubes. It may be necessary to figure out what a tube is without benefit of a tube manual. For receiving tubes, the first number is the heater voltage, the letter(s) are arbitrary, and the final number is the number of elements. (Internally connected elements like suppressors tied to cathodes usually don't count in the number; internal shields and jumpers usually do.) Example: the 12AU7, a 12-volt dual triode with all elements brought out separately. For certain transmitting tubes, the numbers are arbitrary but the letter in the middle gives the number of

elements: "B," diode; "C," triode; "D," tetrode; "E," beam tetrode. Examples are the 3B28 rectifier, 2C39 triode, 2D21 gas tetrode, and 2E26 beam tetrode. The coding system does not differentiate between single and multiple tube sections.

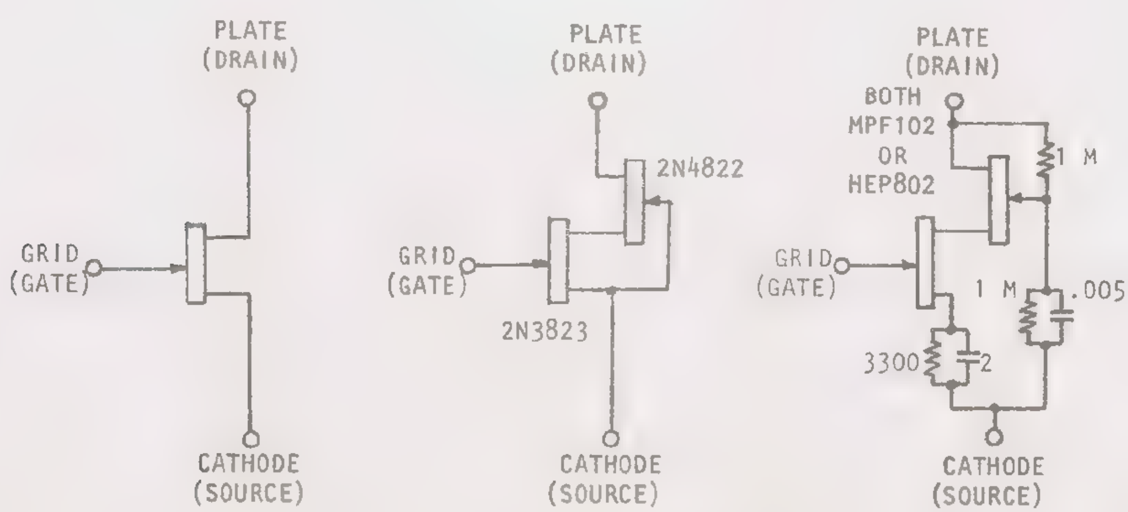
New tubes for European equipment may become particularly hard to find in the future. Table C will be helpful here. If all else fails, and no diagram or instruction manual is available, the coding scheme used by some European tubes is shown in Table C. As an example, an EBF32 is a 6-volt dual-diode-pentode. However, there are many tubes with letter-number codes that don't follow this system.

Some stations may still have old Western Electric or military equipment. Tables D, E, and F show equivalents for certain WECo, industrial/military, and VT-coded tubes respectively.

Stocking Up. The fast-climbing prices of tubes make it sensible to stock up now on tubes that are becoming scarce. It is wise to make up a list of tube gear with its expected retirement year, then to compare the tubes with a list of types that are likely to stay readily available. A good idea of types in this "popular" class appears in Table G. Then order and pack away enough spares of the unlisted types to carry the equipment until it can be replaced. Another reason to stock liberally now is that the eventual resale value of the equipment will be a lot higher if sold with spares.

With prices climbing as fast as they are, it is hard to go wrong economically by stocking up now. That is, a dollar spent on tubes today will save $1.15 worth next year, or $1.32 two years hence. The same dollar put into a savings account will return only about 5½ cents' interest in a year, or slightly less than the rate of inflation. It would be foolish to have to replace $2000 or $3000 worth of transmitter(s) when $200 worth of spare tubes today will keep the equipment going for at least five years more.

In theory, a buy-now program can only speed the end of tube manufacture. However, the tube purchases of the whole college-radio industry are only a tiny part of the total. The issue is solely one of protecting your station's interests - of buying time until the station can raise money to buy solid-state equipment.



FET REPLACEMENTS FOR TUBES

TABLE A

Transistor Ratings

	2N3823	2N4882	MPF102
Transconductance (μmhos)	3500-6500		2000-7500
Noise Figure (dB)	2.5-3		
Breakdown Voltage	30	300	25

TABLE B

Equivalents of European Tubes

Most of these are exact equivalents. Others are close enough for general use.

European	American	European	American	European	American
A1834	6AS7GA	CV452	6AT6	DF91	1T4
A2900	12AT7	CV453	6BE6	DF92	1L4
AA91E	6AL5W	CV454	6BA6	DF904	1U4
A4051	807	CV455	12AT7	DH63	6Q7
A4051J	807	CV491	12AU7	DH77	6AT6
AG	83	CV492	12AX7A	DH81	7B6
AG866A	806A	CV493	6X4	DH147	6Q7G
AG5211	0A2	CV503	5V4GA	DH149	7C6
AGS512	2D21	CV510	6V6	DH150	6CV7
AH201	866A	CV511	6V6GT	DK32	1A7GT
ARS25	807	CV515	6Y6G	DK91	1R5
ARS25A	807	CV537	12SA7	DL33	3Q5GT
B36	12SN7GT	CV538	12SA7	DL35	1C5GT
B65	6SN7GT	CV574	6X5GT	DL36	1Q5GT
B152	12AT7	CV586	6L6GC	DL91	1S4
B309	12AT7	CV628	811A	DL92	3S4
B319	7AN7	CV731	6V6GT	DL93	3A4
B329	12AU7	CV741	6CA7	DL94	3V4
B339	12AX7	CV858	6J6A	DL95	3Q4
B719	6AQ8	CV1060	807	DL96	3C4
BF61	6CK5	CV3523	6146B	DL98	3B4
BPM04	6AQ5	CV3929	5840	DL620	5672
C143	813	CV3993	6688	DP61	6AK5
C180	832A	CV4039	5763	DY30	1B3GT
C866	866	D2M9	6AL5	DY80	1X2A
CR27	866A	D63	6H6	DY86	1S2
CV26	813	D77	6AL5	DY87	1S2A
CV32	866A	D152	6AL5	E88CC	6BQ7A
CV124	807	DAF90	1A3	E180F	6688
CV133	6C4	DAF91	1S5	EA76	5647
CV143	813	DAF92	1U5	EAA91	6AL5
CV144	829B	DCC90	3A5	EABC80	6AK8
CV177	813	DD6	6AL5	EAF42	6CT7
CV216	0D3	DDR7	6AM5	EB34	6H6
CV283	6AL5	DF33	1N5GT	EB91	6AL5
CV424	5894	DF60	5678	EBC33	6Q7G

European	American	European	American	European	American
EBC41	6CV7	ECL86	6GW8	EY81	6R3
EBC80	6BD7	ED2	6AL5	EY82	6N3
EBC81	6BD7A	EF22	7G7	EY86	6S2
EBC90	6AT6	EF41	6CJ5	EY87	6S2A
EBC91	6AV6	EF72	5840	EY88	6AL3
EBF80	6N8	EF80	6BX6	EZ35	6X5GT
EBF81	6AD8	EF81	6BH5	EZ40	6BT4
EBF83	6DR8	EF85	6BY7	EZ80	6V4
EBF89	6DC8	EF86	6CF8/6267	EZ81	6CA4
EC55	5861	EF89	6DA6	EZ90	6X4
EC80	6Q4	EF89F	6DG7	EZ91	6AV4
EC81	6R4	EF91	6AM6	GZ30	5Z4
EC86	6CM4	EF92	6CQ6	GZ31	5U4GB
EC88	6DL4	EF93	6BA6	GZ32	5V4G
EC90	6C4	EF94	6AU6A	GZ34	5AR4
EC91	6AQ4	EF95	6AK5	H52	5U4GB
EC92	6AB4	EF96	6AG5	H63	6F5GT
EC93	6BS4	EF183	6EH7	HAA91	12AL5
EC94	6AF4	EF184	6EJ7	HABC80	19T8
EC95	6ER5	EFL200	6U9	HBC90	12AT6
EC97	6FY5	EH90	6CS6	HBC91	12AV6
ECC32	6SN7GTB	EK90	6BE6	HCC85	17EW8
ECC33	6SN7	EL34	6CA7	HD14	1H5
ECC35	6SL7GT	EL36	6CM5	HD30	3B4
ECC81	12AT7	EL37	6L6GC	HF93	12BA6
ECC82	12AU7	EL38	6CN6	HF94	12AU6
ECC83	12AX7	EL41	6CK5	HK90	12BE6
ECC84	6CW7	EL80	6M5	HL90	19AQ5
ECC85	6AQ8	EL81	6CJ6	HL92	50C5
ECC86	6GM8	EL83	6CK6	HM04	6BE6
ECC88	6DJ8	EL84	6BQ5	HY90	35W4
ECC89	6FC7	EL85	6BN5	KT32	25L6GT
ECC91	6J6	EL86	6CW5	KT63	6F6GT
ECC180	6BQ7A	EL90	6AQ5A	KT66	6L6GC
ECC189	6ES8	EL91	6AM5	KT71	50L6GT
ECC801	6201	EL95	6DL5	KT88	6550
ECF200	6X9	EL181	12BY7A	KTW63	6K7
ECF201	6U9	EL500	6GB5	KTZ63	6J7GT
ECF80	6BL8	EL821	6CH6	L63	6J5
ECF82	6U8A	EM34	6CD7	L77	6C4
ECF86	6HG8	EM35	6U5	LCF80	6LN8
ECF801	6GJ7	EM80	6BR5	LCF86	5HG8
ECF802	6JW8	EM81	6DA5	LCF201	5U9
ECH42	6C9	EM84	6FG6	LCF801	5GJ7
ECH80	6AN7	EM87	6HU6	LCF802	6LX8
ECH81	6AJ8	EN91	2D21	LF183	4EH7
ECH83	6DS8	EN92	5696	LF184	4EJ7
ECL80	6AB8	EN93	6D4	LL86	10CW5
ECL82	6BM8	EQ80	6BE7	LL500	18GB5
ECL84	6DX8	EY51	6X2	LFL200	11Y9
ECL85	6GV8	EY80	6U3	LN152	6AB8

-MORE-

European	American
N14	1C5GT
N16	3Q5GT
N17	3S4
N18	3Q4
N19	3V4
N78	6BJ5
N144	6AN5
N150	6CK5
N709	6BQ5
N727	6AQ5A
0149	7Y4
PABC80	9AK8
PC900	4HA5
PCC84	7AN7
PCC85	9AQ8
PCC88	7DJ8
PCF80	9A8
PCF82	9U8A
PCF801	8GJ7
PCL82	16A8
PCL84	15DQ8
PCL85	18GV8
PL21	2D21
PL81	21A6
PL500	27GB5
PM04	6BA6
PM05	6AK5
QE06/50	807
QQV03-10	6360
QV06-20	6146A
R16	1T2
RE1	5Y3GT
SP6	6AM6
T2M05	6J6
TM12	6J4
U37	1T2
U43	6X2
U41	1B3GT
U50	5Y3GT
U52	5U4GB
U70	6X5GT
U78	6X4
U147	6X5GT
U150	6BT4
U151	6X2
U709	6CA4
UAF42	12S7
UBC41	14L7
UCH42	14K7
UCL82	50BM8
UF41	12CA5

European	American
UF89	12DA6
UL84	45B5
UQ80	12BE7
V2M70	6X4
V61	6BT4
VP6	6CQ6
W17	1T4
W63	6K7
W149	7B7
WD709	6N8
WT294	0D3
X14	1A7GT
X17	1R5
X63	6A8
X65	6K8
X66	6K8
X79	6AE8
X719	6AJ8
X727	6BE6
XCC189	4ES8
XCF80	4BL8
XCL85	9GV8
XF183	3EH7
XF184	3EJ7
XL500	13GB5
Y61	6U5
YF183	4EH7
YF184	4EJ7
XY88	16AQ3
Z63	6J7
Z77	6AM6
Z152	6BX6
Z719	6BX6
Z729	6267
ZD17	1S5
ZD152	6N8
1C1	1R5
1D13	1A3
1F2	1L4
1F3	1T4
1FD9	1S5
1G50	2050A
1P1	3C4
1P10	3S4
1P11	3V4
1R5-SF	1AQ5
1S5-SF	1AR5
1T4-SF	1AM4
1U5-SF	1AS5
2B-250A	807
2XM600A	866A

European	American
3S4-SF	3W4
4G280K	2D21
4Y25	807
5C/100A	813
5S1	807
5Z10	5U4GB
6D2	6AL5
6F12	6AM6
6F18	6EC7
6F22	6267
6F31	6BA6
6L13	12AX7
6L31	6AQ5A
6L34	6AQ4
6LD3	6CV7
6M1	6U5
6M-HH3	6J6A
6P9	6BM5
6P15	6BQ5
6V4	6CA4
6Z4	6X4
7D9	6AM5
7D10	6CH6
7D11	6550
8D3	6AM6
8D5	6BR7
8D7	6BS7
9D6	6CQ6
12E13	6550
12F31	12BA6
12H31	12BE6
12R-LL3	12AV7
13D2	6SN7GTB
20A3	2D21
30F5	7ED7
30L1	7AN7
30P12	12FB5
52KU	5Z4G
62DDT	6CV7
62VP	6CJ5
63ME	6U5
63T1	6AB8
64SPT	6BX6
65ME	6BR5
66KU	6BT4
67PT	6CK5
108C1	0B2
150C2	0A2
150C3	0D3
866AX	866A
3874A	813

-MORE-

TABLE C

Coding System - European Types

First letter:	heater voltage*
D	1.5
G	5
E	6.3
H	12 to 17.5
L, P, X	undefined

Following letter(s):	tube type
A	low-power diode
B	low-power dual-diode
C	triode
F	pentode
L	beam tetrode
K	pentagrid converter
M	electron-ray ("magic eye") indicator
Y	high-voltage diode
Z	dual high-power diode

Following two or three digits: arbitrary.

*For a dual-voltage like the ECC83/12AX7, the character gives the lower voltage.

TABLE D

Equivalents of Western Electric Tubes

W.E.Co. Type	Equivalent
274B	5U4G
300B	6L6/6550
348A	6J7
396A	2C51
403B	6AK5
404A	5847
408A	6028
417A	5842
421A	5998
422A	5U4GB
443A	6388

-MORE-

TABLE E

Equivalents of Industrial & Military Types

The original tubes shown were tested to meet tightened specifications for noise, stability, or ruggedness. In most broadcast applications the conventional types shown will suffice.

1612	6L7	6063	6X4	6664	6AB4
1614	6L6	6066	6AT6	6669	6AQ5
1620	6J7	6067	12AU7	6676	6CB6
1621	6F6	6072*	12AY7	6677	6CL6
1622	6L6	6073	0A2	6678	6U8
1625°	807	6074	0B2	6679	12AT7
1634	12SC7	6080	6AS7G	6680	12AU7
1644	12L8GT	6087%	5Y3GT	6681	12AX7
5591#	6AK5	6095	6AQ5	6829	12AV7
5654	6AK5	6096	6AK5	6913	12BH7
5670*	2C51	6097	6AL5	6928#	6AQ5
5679@	7A6	6100	6C4	6968	6AK5
5691*	6SL7GT	6101	6J6	7025	12AX7
5692	6SN7GT	6106%	5Y3GT	7036	6BE6
5693	6SJ7	6113	6SL7GT	7189	6BQ5
5725	6AS6	6134	6AC7	7212	6146
5726	6AL5	6135*	6C4	7244	6J6
5727	2D21	6136	6AU6	7245A%	6J4
5749	6BA6	6137	6SK7	7318*	12AU7
5750	6BE6	6180	6SN7GT	7220	6BQ5
5751*	12AX7	6186	6AG5	7408	6V6GT
5814*	12AU7	6187	6AS6	7543	6AU6
5824	25B6G	6188	6SU7WGT	7581	6L6GC
5844#	6J6	6189	12AU7	7717	6CY5
5852*	6X5	6197	6CL6	7724	14GT8
5871	6V6GT	6201	12AT7	7728	12AT7
5881	6L6GC	6202	6X4	7729	12AX7
5915	6BE6	6203*$	6X4	7730	12AU7
5930	2A3	6265*	6BH6	7731	6U8
5931	5U4G	6384	6AR6	7732	6CB6
5932	6L6G	6385*	2C51	7733	12BY7
5965	12AV7	6386*	2C51	7734	6GE8
5992*	6V6GT	6485	6AH6	7738	6AN4
6005	6AQ5	6520	6AS7G	7803	6FW8
6045#	6J6	6626	0A2	VR75	0A3
6046	25L6GT	6627	0B2	VR90	0B3
6057	12AX7	6660	6BA6	VR105	0C3
6058	6AL5	6661	6BH6	VR150	0D3
6060	12AT7	6662	6BJ6		
6061	6BW6	6663	6AL5		

Lower heater current than commercial type.
* Higher heater current than commercial type.
@ Center-tapped heater.
% Cathode type.
$ Different base.
° 12-volt heater.

-MORE-

TABLE F

Equivalents of Old Military "VT" Types

VT Number	Equivalent	VT Number	Equivalent	VT Number	Equivalent
41	851	139	0D3	206A	5V4G
42	872	140	1628	207	12AH7GT
46	866	144	813	208	7B8
65	6C5	145	5Z3	209	12SG7
66	6F6	146	1N5GT	210	1S4
68	6B7	147	1A7GT	211	6SG7
69	6D6	148	1D8GT	212	958
70	6F7	149	3A8GT	213A	6L5G
74	5Z4	150	6SA7	214	12H6
80	80	151	6A8GT	215	6E5
83	83	152	6K6GT	216	816
84	6Z4	153	12C8	217	811
86	6K7	154	814	221	3Q5GT
87	6L7	161	12SA7	222	884
88	6R7	162	12SJ7	223	1H5GT
90	6H6	163	6C8G	229	6SL7GT
91	6J7	164	1619	230	350A
92	6Q7	165	1624	231	6SN7GT
93	6B8	167	6K8	233	6SR7
94	6J5	168A	6Y6G	236	836
95	2A3	169	12C8	237	957
96	6N7	170	1E5GP	238	956
97	5W4	171	1R5	239	1LE3
98	6J5	172	1S5	241	7E5
99	6F8G	173	1T4	243	7C4
100	807	174	3S4	244	5U4G
101	837	175	1613	245	2050
103	6SQ7	176	6AB7	246	918
104	12SQ7	177	1LH4	247	6AG7
105	[illegible]	178	1LC6	250	EF50
106	803	179	1LN5	259	829
107	6V6	181	7Z4	260	0A3
112	6AC7	182	3B7	264	3Q4
114	5T4	183	1R4	266	1616
115	[illegible]	184	0B3	268	12SC7
116	[illegible]	185	3D6	277	417
117	6SK7	138	7E6	286	832A
118	832	189	7F7	287	815
119	2X2	190	7H7	288	12SH7
124	1A5GT	192	7A4	289	12SL7GT
125	1C5GT	193	7C7		
126	6X5	194	7J7		
128	1630	196	6W5G		
131	12SK7	197A	5Y3GT		
132	12K8	198A	6G6G		
133	12SR7	199	6SS7		
134	12A6	200	0B3		
135	12J5GT	201	25L6		
136	1625	202	9002		
137	1626	203	9003		
138	1629	205	6ST7		

-MORE-

TABLE D

Tubes Considered Relatively Likely to Remain Available

1B3GT	6AQ5A	6EJ7	6JS6B	8CG7
1K3GT	6AU6A	6EW6	6JU8A	12AT7
1V2	6AW8A	6GF7A	6KA8	12AU7
2AV2	6BA6	6GH8A	6KD6	12AV6
3A3	6BA11	6GJ7	6KE8	12AX7A
3AT2	6BK4C	6GM6	6KT8	12BA6
3CJ3A	6BL8	6GU7	6KZ8	12BE6
3DB3	6BQ5	6GY6	6LB6	12BY7A
3GK5	6BZ6	6HM5	6L6GC	12GN7A
3HM5	6CB6A	6HV5A	6LU8	17JZ8
4EJ7	6CG7	6HZ6	6U8A	33GY7A
5GH8	6CG8A	6JC6	6U10	35W4
5LJ8	6CJ3	6LQ6	6V6GTA	38HE7
5U4GB	6EA8	6JH6	6Z10	50C5

Notes on Class D FM
(Updated from Journal of College Radio, Feb., 1974)

Class "D" FM stations now number about 400, and are growing at about 10% per year. A great many new or carrier-current stations have found 10-watt FM to be a good medium, either in its own right or as a step toward high-power FM. These notes detail some of the considerations in planning and applying for a construction permit. The requirements for high-power FM are so much more strict than for 10-watt operation that it makes little sense to apply for a Class A station of just a few hundred watts - for nearly the same effort and cost, 500 or 1000 watts are reasonable. This tends to accentuate the differences between Class D and high-power operation.

Getting Help

MH Sections 24.00-25.21 and 67.00-67.90 contain a useful summary of the procedures involved in dealing with the FCC. The IBS Engineering Manager can help with specific questions that may arise.

It is not generally wise to expect help from FCC field offices, particularly when doing a frequency search. It is highly unlikely that the local personnel will be able to suggest a suitable channel, and they have been reported to say "no" on general principles when asked about availability of frequencies. They may be able to supply useful data on existing stations for frequency coordination, like height-above-average-terrain in the direction toward your proposed service area.

Consulting engineers can be located, in the absence of a more direct contact, by checking the listings in the "IEEE Spectrum," "Broadcasting," or *Broadcasting Yearbook*. The National Society of Professional Engineers upholds a code of ethics which limits public notices to "firm name, address, telephone number appropriate symbol, name of principal participants and the field of practice in which the firm is qualified." Consulting engineers are thus forbidden to use advertising as such. However, firms that do FM application work without calling themselves "consulting engineers" may advertise, and do so in the Journal of College Radio.

Frequency Selection

If the station is located in an area relatively free from FM channel congestion and without a Channel 6 TV station, the work of finding a frequency can be done by a reasonably skilled chief engineer. The FCC assignment rules for 10-watt operation are Sections 73.501, 502, 505, 506, and 509. The interference-protection rules in 73.509 are newly transplanted from a footnote to Section 1.572.

Stations within 199 miles of Mexico can be built anywhere. However, they must protect existing or potential stations listed in the Table of Assignments (73.504) and also protect Mexican commercial stations on "educational" frequencies. To do this, they must observe the mileage-separation limits in 73.507.

Class D stations need not observe any minimum mileage separations from other educational stations (except in the Mexican-border area). However,

Class D stations on 91.5, 91.7, or 91.9 MHz must preserve minimum spacings from commercial stations 10.6 or 10.8 MHz higher, as detailed in Section 73.207(a). In cases where interference coodination with other educational stations is difficult, part of the transmitter power can be put into vertical polarization to bring the predicted interference contours in closer.

Section 73.515 gives special coordination instructions for stations located in a rectangular area centered roughly on Monterey, West Virginia, and extending about 60 miles in each direction. Other instructions are included for stations in northeastern Colorado.

Calculations of the contours of other stations must be based upon the stations' records as filed with the FCC (either Washington or the local field office). Field office records are not necessarily up-to-date, so if one doesn't mind showing his hand, it is possible to review the public file at the other station. Under Part 1.526, any Commission licensee must make a complete file available for public inspection. The file must be in an accessible public place in the community of license, open during normal business hours. The visitor need give no information other than name and address. Failure to cooperate on the part of the station is grounds for a letter to the Complaints and Compliance Division of the FCC, which will then invite the offender to mend its ways.

If things look at all sticky, it is prudent to have a consulting engineer make a frequency search. It will cost \$200 or \$300, but in many cases is the only way to get a good answer. The search is valid only as long as a new applicant doesn't appear, of course, so a recheck before filing is in order.

If the transmitter is to be in an urban area, the true coverage area will not be a simple circle, but a cross-shaped zone aligned with the street pattern (2). This occurs because the buildings along a street act like the walls of a waveguide. (Coverage predicted according to the Rules ignores this fact.)

If a choice exists, the channel should allow conversion to higher power at a later date without interference to or from other stations. It is usually difficult to persuade another station to change frequency to accommodate a power increase, even with all costs paid.

The presence of a Channel 6 television station is troublesome. In past years, the Commission rejected applications below 90 MHz and insisted on colocation of the FM station on the Channel 6 tower. This issue has been under consideration in Dockets 19183 and 20735 for some time. Fortunately, in recent years the FCC's policy has been much more reasonable.

In tight-squeeze situations, one must follow the footnote to 1.573 and use the "F(50, 10)" chart to figure interfering signal strengths. This chart is available as Figure 1a of Section 73.333. However, the F(50, 10) chart does not apply below ten miles from the transmitter. For the short distances involved in 10-watt operation, the time-variability disappears and the "F(50, 50)" chart will work with less than one decibel of error.

The coverage of a 10-watt station may be insufficient to reach surrounding communities. In this case an on-frequency "booster" or an off-frequency translator may provide satisfactory extension of coverage (3). The translator output is limited to one watt east of the Mississippi River and 10 watts west of it, but there is no limit on antenna gain. Requirements for measurements and operator licenses are quite reasonable. The rules for this service are 74.1201 through 74.1284. Translator applications are made on FCC Form 346. The latest edition of the type-acceptance

list will show what equipment is suitable.

In towns where a CATV system carries FM radio signals, the new station should deliver a good signal at the cable head-end location. Otherwise it is necessary to use a telephone line and FM modulator to feed the CATV system. (This can actually be an advantage because of the possibility of advertising over the cable.)

Transmitter Location

With luck, a high [illegible] on-campus for the transmitter, or a tower can be [illegible]. But if a height of a hundred feet or so is no[illegible] to go off-campus.

Sites held [illegible] have obvious appeal. Real estate, access roads [illegible] other expensive necessities are already [illegible] of tower lighting. Under Section 1.915, [illegible] how the existing antenna structure is affected.

If the station is an AM, of course, a decoupling choke will be needed to bridge the [illegible] tower base insulator. With a shared site, contract [illegible] feasible, although it deprives the Class D engineering staff of the experience and pride of caring for their own transmitter. Charges of at least $500 a year for the program and control lines are in prospect unless a microwave STL is used.

If one is considering renting tower space, UHF-TV stations generally need income worse than VHF, and are likely to be more reasonable.

If the station is planning to build its own remote site, it is good to check with the communications engineer for the local city or county. Such people tend [illegible] land availability, access roads and related [illegible] to locate second-phone technicians.

It is illegal [illegible] of transmitter building, tower, or equipment installation without a construction permit. Equipment may be ordered in advance, and some manufacturers will accept an order contingent upon a CP being granted for a surcharge of about five percent. Actual construction must be in accordance with the station license, even to details [illegible] possible for granting of a CP is [illegible]. Ninety days is typical for an uncomplicated case.

[illegible]

[illegible] options on transmitters. New solid-state [illegible] Tube models are about [illegible] to buy spare tubes in the future [illegible]

Transmitter manufacturers also sell reconditioned used units for about half the new price, although they don't publicize the fact. And a great many obsolete 10-watt exciters can be pressed into service. Dealers in used broadcast equipment (4) or local stations may be able to help here, although one should be satisfied that the equipment is not being sold because of some obscure or intermittent defect.

In choosing a new transmitter, it is advisable to check the maker's manual. A clear and complete instruction manual is essential. The quality of the manual is a good index of the thoroughness of the manufacturer's whole job.

The transmitter should be bought with three copies of the instruction book: one for the transmitter site, one for the chief engineer's files, and one for [illegible]. This will preserve the

resale value of the unit if the manufacturer (ITA or Standard Electronics, for example) goes out of business and the manuals are lost.

Stereo operation is NOT recommended for Class D use, and only about five percent of all 10-watt stations operate stereo. There is inadequate margin for the noise degradation, commonly estimated as 23 dB (5), that stereo brings. (If you want stereo like the big boys, a Class A license is a must!)

Commercial broadcasters may be interested in donating used equipment, particularly if reminded that gifts to an educational institution are tax-deductible. The same is true of the rental value of a transmitter site and tower space if donated.

Transmitter types may be changed between the granting of a CP and the filing for a station license. As long as the equipment is type-accepted, just show the new model on Form 341.

Choosing an Antenna

Too many Class D stations use a two-bay antenna, at whatever height the Speech and Drama building happens to provide. This is a fundamental mistake which guarantees that the station will be barely audible beyond the campus boundary, and wastes good frequency spectrum besides. Any organization that is serious about running a radio station will seek a more effective facility.

For effective coverage, a multi-bay antenna and some height are essential. Figure 1 shows the coverage areas enclosed by the 1-mV/m contour provided by one, two, four, or eight bays at various heights. It is adopted from Section 73.333 by assuming a 10-watt transmitter, one decibel of feed-line loss, and flat ground. Note that under typical conditions, doubling the number of bays gives about 50% more coverage area. Doubling the height gives about 100% more area. Doubling both (from two bays at 100 feet to four at 200 feet, say) triples the coverage.

With low-power bays at a bout $250 each and towers at a few dollars a foot, there is little reason not to have an effective antenna.

Not many class D stations presently use part-vertical or circular polarization. At least some vertical energy is desirable to fill in shadowed areas and to enhance reception on portable and car receivers.

The feedline to be used will naturally affect the cost of the installation. Some hints on selection and installation of feedlines are available in MH Section 68.00. One can allow as much as one dB of line loss (80% efficiency) without appreciably degrading the coverage area. Table A shows the lengths of various coaxial lines, each giving one dB at 90 MHz, and the cost for that length.

Lines that can be pressurized have the great advantage that as long as the line holds pressure, one knows that no water contamination is present.

Some antenna makers, Cablewave, CCA, and Gates among them, sell low-power bays at about 40% of the price of high-power ones. These are a natural choice for Class D, and will accept a couple of hundred watts each if one goes to Class A operation later. Alternatively, one can home-make "halo" bays at low cost.

Power splitters are easy to home-make inexpensively. Figure 2 shows a simple splitter suitable for combining two 50-ohm bays. This splitter can be used in multiple to derive 4- or 8-element branching feeds.

Antenna tuning and SWR are not particularly critical at the 10-watt level. There is no danger of breaking down a transmission line or transmitter from excessive SWR. An SWR as bad as 4:1 will reduce the listeners'

signal by only 2 dB, and the coverage area by about 19%. Thus, antenna deicers are not necessary except in exceptional cases. (A badly detuned antenna will give higher audio distortion, however.)

Audio Program Lines

If the transmitter will be located away from the studios, a telephone line is required. A 15-kHz equalized line runs $32.50 per month within the local telephone exchange area. A nonequalized loop costs only $10.80, but may or may not be equalizable to 15 kHz. Most across-the-campus loops are. Any loop whose loss measures 30 dB or less at 15 kHz, as measured through a 600:150 ohm transformer at the studio and a 150:600 transformer at the transmitter, can be equalized plus or minus one decibel to 15 kHz. See MH Section 54.12 for more details.

A control loop ("0-30 baud channel") will be needed for on-off control of the transmitter unless one buys a nonequalized audio loop and adds a "simplex" connection to derive an additional ground-return control function from it. Remote metering is not required.

Compressors and Limiters

Audio compression and limiting are even more important with Class D FM than with higher power. Only by maintaining adequate modulation levels can the station reach its full potential audience.

The limiter should be a special FM type to guard effectively against overmodulation on high-frequency peaks. A conventional AM type can be pressed into service by locating it between the preemphasis network and the transmitter, or by adding an RC high-frequency-boost network with 75-microsecond time constant to its level detector circuit.

Transmitter Monitoring

The frequency and modulation level of the transmitter must be checked periodically. If a commercial monitoring service is not within listening range and other frequency measurement means are unavailable, it will be necessary to buy a frequency counter or monitor. The transmitter meters alone do not guarantee correct operation. On at least one transmitter, the meters can show normal phase-lock while the transmitter is 300 kHz off-frequency. Another thing to be wary of: monitors using a 200-kHz IF, like the H-P 335, will show zero frequency error if the transmitter is off by exactly two channels, like 89.7 instead of 90.1 MHz.

A modulation monitor can be improvised by connecting a VU meter to an FM tuner and calibrating against other stations.

(The fact that the transmitter is type-accepted is no indication that it is a good design or that it operates within the Rules. It simply means that the manufacturer once got a prototype to work satisfactorily and was able to document the fact. Hence the need for adequate monitoring.)

Emergency Power

It is easy to provide standby power at the 10-watt level. A good-sized car battery and 117-volt inverter will keep a tube transmitter on the air for about five hours, and a solid-state one for about 18. If essential studio equipment is protected similarly, the station becomes a valuable community resource during emergencies.

For planning a standby power system, Figure 3 shows the current-time ratings of typical lead-acid batteries of various ampere-hour capacities.

Maintenance Personnel

The Class D station needs a second- or first-class licensee to perform transmitter maintenance. If the station or school staff doesn't include a licensed technician, it is necessary to contract out the work at considerable cost. In some areas a commercial broadcast maintenance

firm is available. In others, it is necessary to find an outside engineer. Likely people are engineers at other stations, retired broadcast engineers, telephone microwave technicians, and mobile radio repairmen (CB, police, taxi, or telephone company). It is probably wise to pay a monthly retainer fee so as to assure prompt attention when a failure occurs.

Funding Considerations

In raising funds (from alumni, say) it is good psychology to solicit donations contingent upon the CP's being granted. The prospective donor is much more likely to sign up if he thinks there's a good chance that his pledge won't be collected.

The record low cost for getting a Class D station on the air, including studios, is about $500. The station in question collected a large assembly of old equipment and even resorted to such heroic measures as home-made turntable arms.

The FCC expects each applicant to be properly funded to complete and operate the station. Form 340 asks some rather specific questions along this line.

Administrative Matters

Be sure to use the latest editions of Forms 340 and 341 (they're changed from time to time). It is safer to get them from the FCC in Washington than a field office.

It is important to get the application right the first time. Defective applications are returned for correction, and in the interim someone else may file for the channel or an adjacent frequency. The school's legal staff may want to scrutinize the application; after all, the Board of Trustees is usually the actual licensee. But attorneys aren't trained to detect errors in the engineering filing.

Be sure to check for typographical errors on any document from the FCC, like erroneous geographical coordinates. Any mistake becomes your problem if the inspector comes around. In case of an error, a polite letter should suffice to have the document reissued.

Remote-control authorization is necessary if the transmitter is out of the studios or even out of sight of the board operator.

Lighting may be necessary if the antenna is more than 20 feet above an existing structure. In such cases, an aeronautical showing is required on the CP application, with possibly a filing of FAA Form 7460-1.

Class D stations are normally assumed to operate at 100 feet above average terrain. If the new station will be higher, it is good to get that fact into the record by including the radial study in the engineering filing. This buys protection against interference from an outside station.

As far as the preparation and signing of the technical portions of Forms 340 and 341 goes, the FCC does not require specific educational or licensing qualifications of the person doing the work. However, state laws usually make it unlawful for any non-registered engineer to use the titles "consulting engineer" or "professional engineer." To avoid legal complications, it is wise to stick to "technical director" when completing the forms.

Reference Material

An applicant needs the following material:

Volumes I and III of Federal Communications Commission Rules and Regulations, available for $27 from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. This buys

subscriptions to Parts 0, 1, 17, and 73, among others. Allow at least six months for delivery. (It is interesting to note that the cost of a full set of FCC Rules has about quadrupled since 1964.) While awaiting delivery, one can find the Rules at a local station, an FCC field office, some Department of Commerce offices, or a law library (although library copies may not be up-to-date). The Rules are Title 47 of the Code of Federal Regulations.

- Forms 340 and 341 (six copies) from a field office or the Federal Communications Commission, Washington, D.C. 20554. Part 0.121 of the Rules gives the addresses of all field offices.
- FAA Sectional Aeronautical Chart or (whenever possible) the Instrument Landing Chart for the local airport (five copies). Instrument approach charts are available for $1 apiece from Jeppesen & Co., 8025 E. 40th Ave., Denver, Colorado 80207, or from local flight suppliers. The sectional chart is ordinarily used only when the station is 10 or more miles from the airport. Mark in any new airstrip built since the map was issued.
- U.S. Geological Survey topographic quadrangle maps (four copies) for the area within 15 miles for the proposed transmitter location. Maps, map indexes, and order forms are available from the U.S. Geological Survey Map Office, 1200 Eads St., Arlington, Virginia 22202, or Federal Center, Bldg. 41, Denver, Colorado 80225. Topographic map sheets are also available from some large stationers.

The following literature may prove helpful.

- Volume XI, Federal Aviation Regulations, and/or FAA "Obstruction Marking and Lighting Advisory Circular 70/7460-1," from the Superintendent of Documents, $2.75 and $0.60 respectively.
- Administrative Bulletin No. 1, "Printed Publications"; Information Bulletin No. 1-B, "How to Apply for a Broadcast Station"; and "The Public and Broadcasting: A Procedure Manual," all obtainable free from the FCC in Washington. The "Procedure Manual" was printed in the Federal Register for September 29, 1972, and is reprinted as MH Section 27.80.
- "Radio Equipment List - Equipment Acceptable for Licensing," available for inspection at FCC offices, or purchasable from about $25 from the Commission's duplicating contractor (see Section 0.465 of the Rules for the latest contractor's name and address - it changes yearly).
- *Sex and Broadcasting - A Handbook on Starting Community Radio Stations,* by L. W. Milam, 1975, available for $5 from "The Dildo Press Lady" (sic), 131 Wilder, Los Gatos, CA 95030.
- "Broadcast Service List (AM, FM, TV)" and "Pending Applications List - FM," from the FCC duplicating contractor, $25 each (possibly six months out of date by time of receipt).
- "FM Station Atlas," $2.50 from FM Atlas Publishing Co., Box 24, Adolph, Minnesota 55701. This listing is quite convenient for quick-check frequency searches. However, it lists the city of license, not the actual transmitter location, and is thus not authoritative for critical interference cases.

Flow of Applications

The general flow of an application is detailed in Table B.

References

1. K. Bullington, "Radio Propagation Fundamentals," Bell System Technical Journal, May 1957, p. 593; W.R. Young, Jr., "Comparison of Mobile Radio Transmission at 150, 450, 900 and 3700 mc," B.S.T.J., Nov. 1952, p. 1068; K. Bullington, "Radio Propagation Variations at VHF and UHF," Proceedings of the IRE, Jan. 1950, p. 7; J.A. Saxton and J.A. Lane, "VHF and UHF Reception - Effects of Trees and Other Obstacles," Wireless World, May 1955, p. 229; K. Bullington, "Radio Propagation at Frequencies Above 30 mc,"

Proceedings of the IRE, Oct. 1947, p. 1122.
2. W. C. Jakes, Jr., "New Techniques for Mobile Radio," Bell Laboratories Record, Dec. 1970, p. 330.
3. R.A. Jones, "The First US FM Translator," Broadcast Engineering, April 1972, pp. 26-29.
4. "Broadcast Equipment and Supplies," JCR, Oct. 1972, p. 41.
5. S.W. Halpern, "Three-Channel FM Stereo Multiplex System for Compatible Broadcasting," IEEE Transactions on Broadcasting, Sept. 1971, p. 73.

Table A

Cable	Length	Approx. Cost
RG-213(8)	48	$ 11
RG-218(17A)	111	68
1/2" Foam Heliax	114	98
7/8" Foam Heliax	181	271
1-5/8" Foam Heliax	358	1,220

Table B
FM APPLICATION PROCEDURE

YOU		FCC
Complete Form 340; Public Notice in newspapers	→ * →	Notify of receipt; Place on Public Notice
		+ ↓
Begin construction;	← * ←	Grant CP
Suggest call letters	→ * →	Assign call letters
Equipment tests	← * ←	
Notify Field Engineer	→ * →	Inspect Station (rarely, if ever, for Class D)
Informal application to start program tests;	← * ←	
Complete Form 341	→ * →	Authorize "program tests"
"Program tests" (normal operation)	← *(10 days min.) ←	(4-6 weeks) ↓
		Grant License

*Mailing and handling time.
+31 days legal minimum; 60-90 days normally, if no problems or protests.

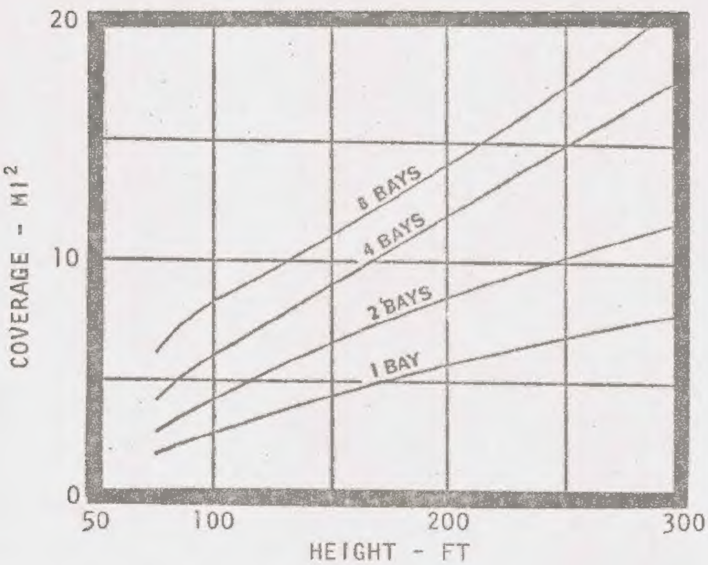


FIG. 1

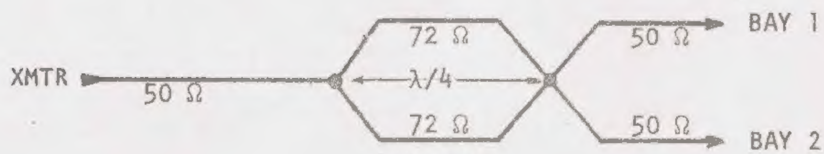


FIG. 2

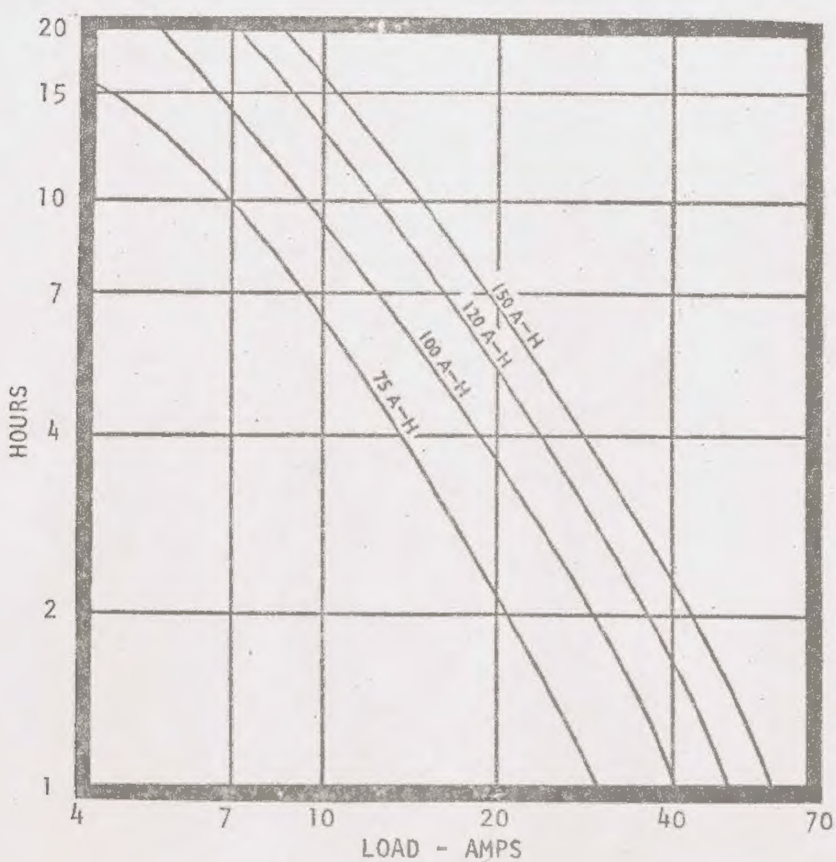


FIG. 3